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SYN2D. A Flux-synthesis Program Based on
a Discontinuous Trial-function Formulation

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TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT	9
1 INTRODUCTION	9
2 USER'S GUIDE TO SYN2D	11
A Program Abstract	11
1 Description of Capabilities	11
2 ARC System Standard Paths Using This Module	11
3 ARC System Data Sets Used by This Module	11
B Mathematical Formulation and Description of Solution	11
1 Introduction	11
2 The Variational Principle	13
3 The Synthesis Assumptions and the Synthesis Equations	21
4 Discrete Approximations and Method of Solution	29
5 Output Edits	37
6 Implementation of Particular Interface Conditions	46
7 Integration Procedures and the Formation of Partial Integrals	47
8 Other Geometries and Synthesis-region Configurations	53
C General Program Description	61
1 Capabilities	61
2 User Options	64
3 Data Sets Used	65
D Description of Program Execution	66
1 Catalogued Procedure Description	66
2 Path Description	71
E Module-dependent Input to SYN2D	72
F Error Messages	76
G Sample Input and Output	91
1 Input	91
2 Output	100
H J2DTOLIB, A Generator Program for Synthesis Trial-function Libraries	126
1 Introduction	126
2 Input Data Sets	126

TABLE OF CONTENTS

	<u>Page</u>
3. Output Data Sets	127
4. Scratch Data Sets Used	127
5. Method of Operation	127
6. Input-card Specifications (J2D Deck)	128
7. Sample Input	128
8. Printed Output Messages and Significance	129
9. JCL and Program Listings	131
 III. PROGRAMMER'S DESCRIPTION OF SYN2D	 135
A. Description of Program Flow	135
1. Overlay Structure	135
2. Description of Program Structure and Flow	136
B. Common-block Descriptions	141
1. BCBLK	141
2. BLKSTH	143
3. HEADER	143
4. NAMBLK	144
5. SINGLE	144
Dynamic Storage Array Allocation	149
D. Subroutine Descriptions	161
1. Subroutine BCONDS	162
2. Subroutine CALC1	163
3. Subroutine CALC2	165
4. Subroutine CHECK	167
5. Subroutine CLOSE	168
6. Subroutine COFGEN	169
7. Subroutine DIMSCT	171
8. Subroutine DSRNCK	172
9. Subroutine DZDCAL	172
10. Subroutine DZDOUT	173
11. Subroutine ERRMSG	173
12. Subroutine FLOP	174
13. Subroutine FLUXPR	175
14. Subroutine FPRIME	175
15. Subroutine GETBND	176
16. Subroutine GETCHI	178
17. Subroutine LAREA	178
18. Subroutine IFXNRM	179
19. Subroutine IFXVOL	180

TABLE OF CONTENTS

	<u>Page</u>
20. Subroutine IGPCAL	180
21. Subroutine ILKCEL	181
22. Subroutine IRGBAL	183
23. Subroutine ITOBAL	184
24. Function IVOL	184
25. Subroutine LIB	185
26. Subroutine MADD	187
27. Subroutine MOVE	187
28. Subroutine MSUB	188
29. Subroutine MTGEN1	188
30. Subroutine MTGEN2	190
31. Subroutine NORM	192
32. Subroutine NUMMLT	193
33. Subroutine PAGHED	193
34. Subroutine PCKSCT	193
35. Subroutine PCOMP	196
36. Subroutine PGEOM	197
37. Subroutine PROCES	197
38. Subroutine PRTBC	199
39. Subroutine RBNDC	199
40. Subroutine RCDEP	201
41. Subroutine RCOMP	201
42. Subroutine RDELAY	202
43. Subroutine RGEOM	202
44. Subroutine RGROUP	203
45. Subroutine RIEMAN	206
46. Subroutine RKIN	209
47. Subroutine RMESH	210
48. Subroutine RRCALC	211
49. Subroutine RSDEF	212
50. Subroutine RVEL	213
51. Subroutine RXSC01	214
52. Subroutine SINCAL	214
53. Subroutine SINOUT	217
54. Subroutine STORBC	218
55. Subroutine SWEEP1	219
56. Subroutine SWEEP2	219
57. Program SYN2D	220
58. Subroutine SYNCAL	220
59. Subroutine SYNDEF	221
60. Subroutine SYNGEN	222
61. Subroutine SYNIN	222
62. Subroutine SYNOUT	223

TABLE OF CONTENTS

	<u>Page</u>
63. Subroutine TWODPR	225
64. Subroutine VALUES	226
E. Data-set Usage	227
1. Data Set A.SYN2D	227
2. Data Set BC	228
3. Data Set FA.TRIAL	228
4. Data Set FR.D2	229
5. Data Set FR.PN	229
6. Data Set FR.TG	229
7. Data Set FR.TRIAL	230
8. Data Set GEOM	231
9. Data Set LIB.ABIT	231
10. Data Set LIB.MIX	233
11. Data Set LIB.PART	233
12. Data Set LIB.REAL	236
13. Data Set SCR001	237
14. Data Set SCR002	240
15. Data Set SCR003	241
16. Data Set SCR004	242
17. Data Set XS.C.MIN	243
18. Data Set XS.ISO2 or XS.ISO	243
19. Unnamed Scratch Data Sets	243
ACKNOWLEDGMENTS	244
REFERENCES	245

LIST OF FIGURES

<u>No.</u>	<u>Title</u>	<u>Page</u>
1	Schematic Representation of the Reactor	14
2	Typical Synthesis Region.	62
3	Typical Two-dimensional xy Reactor Configuration.	127
4	Diagrammatic Subroutine Calling Map	142
5	Bandwidth Structure	195

9

SYN2D: A Flux-synthesis Program Based on a Discontinuous Trial-function Formulation

ABSTRACT

This report presents the documentation of the SYN2D computer program. It consists of two sections. The first is intended for users of the program SYN2D, the second is provided for use by programmers and other individuals who wish to alter the program.

The SYN2D program performs two-dimensional criticality calculations using a single-channel discontinuous-trial-function discretization technique. It can handle rectangular or cylindrical coordinates and it allows for zero flux, zero current, or reflective boundary conditions. The trial functions may or may not satisfy the boundary conditions.

The SYN2D program is structured as a module in the Argonne Reactor Computation (ARC) System and depends on the output of other ARC System computational modules for its input.

1. INTRODUCTION

The body of this report comprises two sections. Section II is intended for users of the program SYN2D. Section III is provided for programmers or other individuals who wish to alter the program.

The SYN2D program is structured as a module in the Argonne Reactor Computation (ARC) System and depends on the output of other ARC System computational modules for its input. The ARC System has been executed on IBM system/360 computer models 50, 75, 85, and 195, under the OS/360 operating system.

The ARC System consists of a library of computational modules for fast-reactor design calculations along with a set of system modules and subroutines which provide an environment for the operation of the computational modules. The modules are used in a selected order by driver programs called paths. Inter-module communication is through ARC system data sets. The data sets are defined such that output from one computational module can be used as input to others. This allows for the automation into a single run of what would normally be a sequence of runs.

ANL-7711¹ is the first volume of a series describing the ARC System. It describes the ARC System history and philosophy, the software environment in which the ARC System operates, the system modules and subroutines which make up the software environment, and the ARC System data sets. It also contains instructions on how to write, use, and maintain paths. The other ARC System computational modules used by the path for SYN2D are described in ANL-7713² and ANL-7714.³

II. USER'S GUIDE TO SYN2D

A. Program Abstract

1. Description of Capabilities

This module uses a flux-synthesis technique to calculate an approximation to the two-dimensional multigroup diffusion equation.

The only capability presently available is a real homogenous k-effective calculation

2. ARC System Standard Paths Using This Module

STP008--Two-dimensional Synthesis Standard Path

ARC System Modules used by STP008

INHOMG (NUI001) Cross-section Homogenization Specifications

GNIP (NUI002) Neutronics Input Processor

HOMOG (NUC001) Cross-section Homogenization

SYN2D (AJC005) Two-dimensional Flux Synthesis

Catalogued Procedure Using This Standard Path

ARCSP008--Invokes the standard path STP008

3. ARC System Data Sets Used by This Module

Upper interface--A. YN2D, BC, FR TG, FR TRIAL, FA TRIAL, G M, LIB.ADJT, LIB.MIX, LIB.PART, LI REAL, and XS.C.MIN

Lower interface--F D2, FR.PN, FR.TG, LIB.ADJT, LIB.MIX, LI PART, and LIB.REAL

B. Mathematical Formulation and Description of Solution

1. Introduction

The continuously increasing demand for more accurate descriptions of the neutron-flux distribution in complex reactor systems has been the driving force behind the development of approximate flux-synthesis techniques to calculate those neutron-flux distributions. Using these

techniques, one obtains a reasonably accurate picture of the neutron-flux distribution at a substantially lower cost than a comparable "exact" calculation using straight finite-difference approximations to the equations of the problem.

The idea of flux synthesis in reactor physics consists of assuming that the multidimensional neutron fluxes in the reactor, let us say $\phi(X_1, X_2, \dots, X_M)$ can be represented with reasonable accuracy by a linear combination of a finite (and usually small) number of known functions $\psi_i(X_1, \dots, X_S)$ of lower dimensionality ($S \leq M$).

$$\phi(X_1, X_2, \dots, X_M) \approx \sum_{i=1}^M \psi_i(X_1, \dots, X_S) C_i(X_{S+1}, \dots, X_M)$$

The functions of $\psi_i(X_1, \dots, X_S)$ are known as the trial functions for the problem. The unknown coefficients $C_i(X_{S+1}, \dots, X_M)$ of the linear combination are usually called the mixing functions.

The independent variables of the problem can be quite diverse for example, the spatial coordinates x, y, z or r, θ, z , the time t , the neutron energy E , and the angle Ω of the neutron motion. The breakdown into variables entering as arguments of the trial functions or of the mixing functions can also be made in various ways selected according to the characteristics of the problem at hand. For example, in a three-dimensional, time-dependent, monoenergetic problem the synthesis assumption could be

$$\phi(x, y, z, t) \approx \sum_{i=1}^M \psi_i(x, y, z) C_i(t)$$

or

$$\phi(x, y, z, t) \approx \sum_{i=1}^M \psi_i(x, y) C_i(z, t)$$

In the first case, the mixing functions are time functions; in the second case, the problem of determining the mixing functions is two-dimensional. Another example. The two-dimensional flux $\phi(r, z)$ can be synthesized as follows

$$\phi(r, z) \approx \sum_{i=1}^M \psi_i(r) C_i(z)$$

or

$$\phi(r, z) \approx \sum_{i=1}^M \psi_i(z) C_i(r),$$

(1)

and the choice between these two options will depend on which one of the expressions is more convenient in the reactor configuration being considered.

The object of a flux-synthesis calculational method is to specify some way of obtaining the mixing functions. Since the synthesis expansions are essentially approximations, the coefficient functions are determined not with the idea of actually obtaining the exact solution, but aiming at an optimum choice as judged with some arbitrarily chosen criterion. The degree of approximation to the real fluxes of these synthesis solutions depends largely on how good a choice of trial functions ψ_i has been made. There are a number of flux-synthesis methods, depending on both the type of trial functions used and the techniques prescribed to determine the mixing functions.

The most successful and commonly used synthesis techniques are the variational and weighted residual methods.

The earliest developments of these techniques were done using continuous sets of trial functions. This means that the same set of trial functions $\psi_i(X_1, \dots, X_S)$ are used throughout the whole range of the variables $X_1, \dots, X_M$. In some cases, though, some of the trial functions $\psi_i(X_1, \dots, X_S)$ used are important only over certain ranges of the variables and could be ignored at other locations in the reactor.

A synthesis method that allows one to do precisely this, that is, to expand the flux in different sets of trial functions at different locations in the reactor is known as a discontinuous trial-function synthesis. Each set of trial functions is used to expand the flux in a partial volume of the reactor. These partial nonoverlapping volumes will be called synthesis regions. The surface between two synthesis regions will be called a synthesis interface. This report develops a variational method using as a basis the functional proposed by Buslik.⁴ An alternative treatment of the discontinuities is introduced by a weighted-residuals method.⁵

The problem that will be used to illustrate the method proposed is the approximate solution of the static multigroup neutron diffusion equations in two-dimensional (r, z) cylindrical coordinates. The synthesis breakdown for the flux will be made as in Eq. 1. The method proposed can be easily adapted to other geometries and number of coordinates as well as to other synthesis expansions.

2. The Variational Principle

The equations for the multigroup problem to be considered are

$$\nabla \cdot (D_g \nabla \phi_g) - \Sigma_{rg} \phi_g + \sum_{g'=1}^{g-1} \Sigma_{g'g} \phi_{g'} + \lambda \chi_g \sum_{g'=1}^G (v \Sigma_{fg'}) \phi_{g'} = 0, \quad g = 1, \dots, G \quad (2)$$

$$\nabla_g \cdot (D_g \nabla \varphi_g^*) - \Sigma_g \varphi_g^* + \sum_{g'=g+1}^G \Sigma_{gg'} \varphi_{g'}^* + \lambda (\nu \Sigma_f)_{-g} \sum_{g'=1}^G \chi_{g'} \varphi_{g'}^* = 0, \quad g = 1, \dots, G, \quad (3)$$
$$\left. \begin{aligned} C_2 \phi_g &= -C_1 D_g \frac{\partial \phi_g}{\partial n} \\ B_2 \phi_g^* &= -B_1 D_g \frac{\partial \phi_g^*}{\partial n} \end{aligned} \right\} g = 1, \dots, G \quad (4)$$

A diagram of a cylindrical shell. A vertical axis is labeled z . The shell is defined by two concentric cylinders with radii R_1 and R_2 . The height of the shell is h , extending from $z=0$ to $z=h$. At the top surface ($z=h$), unit normal vectors $\vec{n}_1$ and $\vec{n}_2$ are shown pointing radially outward from the inner and outer surfaces, respectively. A unit normal vector $\vec{n}_0$ is shown pointing vertically upward from the top surface. The bottom surface is at $z=0$. Dashed lines indicate the projection of the shell onto the $z=0$ plane.

The reactor geometry is represented in Fig. 1. The regions shown, limited by the radii $R_1, R_2, \dots, R_n, \dots$, are synthesis regions where different sets of trial functions will be assumed. For a practical calculation, there may be quite a few of these regions. The trial functions used will be functions of the z coordinate, one set in each region, for both flux and adjoint. The cylindrical surfaces of radii R_i are the surfaces at which the trial function discontinuities occur. θ symmetry is assumed throughout.

The variational functional to be used is

$$f[u_g^k(r, z), u_g^{k*}(r, z), \alpha_g^k(z), \beta_g^k(z)] = \sum_{k=1}^K \left\langle 2\pi \chi_k \sum_{g=1}^G \left\{ \nabla u_g^{k*} \cdot D_g \nabla u_g^k + u_g^{k*} \left[\Sigma_{rg} u_g^k - \sum_{g'=1}^{G-1} \Sigma_{g'g} u_{g'}^k - \lambda x_g = (\nu \Sigma_f)_g u_g^k \right] \right\} r dr dz \right\rangle \quad (5)$$

(Contd.)

$$\begin{aligned}
& - \sum_{k=1}^{K-1} \left\langle 2\pi R_k \int_0^h \sum_{g=1}^G \left\{ \alpha_g^k \left[u_g^{(k+1)}(R_k, z) - u_g^k(R_k, z) \right] \right. \right. \\
& \quad \left. \left. + \left[u_g^{(k+1)*}(R_k, z) - u_g^{k*}(R_k, z) \right] \beta_g^k \right\} dz \right\rangle \\
& + \sum_{g=1}^G \left[\sum_{k=1}^K \left\langle 2\pi \int_{R_{(k-1)}}^{R_k} \left\{ \alpha_{gk}^T u_g^{k*}(r, h) u_g^k(r, h) + (\alpha - 1) \left[u_g^{k*}(r, h) D_g \frac{\partial u_g^k}{\partial z} \right]_{z=h} \right. \right. \right. \\
& \quad \left. \left. + u_g^k(r, h) D_g \frac{\partial u_g^{k*}}{\partial z} \right]_{z=h} \right\} r dr + 2\pi \int_{R_{(k-1)}}^{R_k} \left\{ \beta_{gk}^B u_g^{k*}(r, 0) u_g^k(r, 0) \right. \right. \\
& \quad \left. \left. + (1 - \beta) \left[u_g^{k*}(r, 0) D_g \frac{\partial u_g^k}{\partial z} \right]_{z=0} + u_g^k(r, 0) D_g \frac{\partial u_g^{k*}}{\partial z} \right]_{z=0} \right\} r dr \right\rangle \\
& + 2\pi R_0 \int_0^h \left\{ \gamma C_{gK}^R u_g^{K*}(R, z) u_g^K(R, z) + (\gamma - 1) \left[u_g^{K*}(R, z) D_g \frac{\partial u_g^K}{\partial r} \right]_{r=R} \right. \\
& \quad \left. + u_g^K(R, z) D_g \frac{\partial u_g^{K*}}{\partial r} \right]_{r=R} \right\} dz + 2\pi \int_0^h \left[\frac{\partial u_g^{K*}}{\partial r} \right]_{r=0} \left[\frac{\partial u_g^K}{\partial r} \right]_{r=0} dz \quad (5)
\end{aligned}$$

where

V_k is the volume between $R_{k-1} > r \leq R_k$, $0 \leq z \leq h$,

and

$u_g^{k*}(r, z)$ and $u_g^k(r, z)$ are independent-variable functions defined in the k th synthesis region.

These will be identified later with $\phi_g^{k*}(r, z)$ and $\phi_g^k(r, z)$ when at their stationary values: $\alpha_g^k(z)$, $\beta_g^k(z)$ are functions of z only, defined at the cylindrical surfaces with radius R_k . here are K synthesis regions:

$$R_0 = 0$$

and

$R_K \equiv R$, the outside react r radius,

where δ , α , η , β , θ and ν can take on the values 0 or 1. The choice of these six numbers gives the boundary conditions at the outside of the reactor. Note that ζ and α , β and η , and θ and ν can never be pairwise zero, but can change value with group or synthesis region. The numbers C_{gK}^B , C_{gK}^I and C_{gK}^R are nonzero if $\eta = 0$ or θ are nonzero respectively.

The k -dependence of the parameters in the functional has not been emphasized, since the k boundaries may not be boundaries between different material compositions.

Which among the family of functions $u_g^k(r, z)$, $u_g^{k*}(r, z)$, $\alpha_g^k(z)$, and $\beta_g^k(z)$ will make the functional J stationary? To find out the conditions to be satisfied by the $u_g^k(r, z)$ and β_g^k we transform the first term in the volume integrals in Eq. 5 in the following way, using Green's theorem.

$$\begin{aligned} \sum_{k=1}^K \sum_{g=1}^G 2\pi \int_{V_k} \nabla u_g^{k*} \cdot D_g \nabla u_g^k r dr dz &= \sum_{k=1}^K \sum_{g=1}^G 2\pi \int_{V_k} u_g^{k*} \nabla \cdot (D_g \nabla u_g^k) r dr dz \\ &+ \sum_{k=1}^{K-1} \sum_{g=1}^G \left\{ 2\pi R_k \int_0^h \left[u_g^{k*}(R_k, z) D_g \frac{\partial u_g^k}{\partial r} \right]_{r=R_k} \right. \\ &\quad \left. - u_g^{(k+1)*}(R_k, z) D_g \frac{\partial u_g^{(k+1)}}{\partial r} \right|_{r=R_k} dz \Big\} \\ &- \sum_{k=1}^K \sum_{g=1}^G \left\{ 2\pi \int_{R_{(k-1)}}^{R_k} \left[u_g^{k*}(r, h) D_g \frac{\partial u_g^k}{\partial z} \right]_{z=h} - u_g^{k*}(r, 0) D_g \frac{\partial u_g^k}{\partial z} \right|_{z=0} r dr \Big\} \\ &+ 2\pi R \sum_{g=1}^G \int_0^h \left[u_g^{K*}(R, z) D_g \frac{\partial u_g^K}{\partial r} \right]_{r=R} dz \end{aligned} \quad (6)$$

Introducing this result into Eq. 5, we obtain

$$\begin{aligned} J &= \sum_{k=1}^K 2\pi \sum_{g=1}^G V_k \left\{ u_g^{k*} \left[-\nabla \cdot (D_g \nabla u_g^k) - \Sigma_{rg} u_g^k - \sum_{g'=1}^{g-1} \Sigma_{g'g} u_{g'}^k \right. \right. \\ &\quad \left. \left. - \lambda \chi_g \sum_{g'=1}^G (v \Sigma_{fg'})_g u_{g'}^k \right] r dr dz \right\} \end{aligned} \quad (7)$$

(Contd.)

$$\begin{aligned}
& + \sum_{k=1}^{K-1} \sum_{g=1}^G 2\pi R_k \int_0^h \left\{ \alpha_g^k \left[u_g^{(k+1)}(R_k, z) - u_g^k(R_k, z) \right] \right. \\
& \quad \left. - u_g^{(k+1)*}(R_k, z) \left[\beta_g^k(z) + D_g \frac{\partial u_g^{(k+1)}}{\partial r} \Big|_{r=R_k} \right] + u_g^{k*}(R_k, z) \left[D_g \frac{\partial u_g^k}{\partial r} \Big|_{r=R_k} + \beta_g^k(z) \right] \right\} dz \\
& + \sum_{k=1}^K \sum_{g=1}^G 2\pi \int_{R_{(k-1)}}^{R_k} \left\{ u_g^{k*}(r, h) \left[\zeta \alpha_{gk}^T u_g^k(r, h) + (\zeta(\alpha - 1) + 1) D_g \frac{\partial u_g^k}{\partial z} \Big|_{z=h} \right] \right. \\
& \quad \left. + \frac{\partial u_g^{k*}}{\partial z} \Big|_{z=h} \zeta(\alpha - 1) [D_g u_g^k(r, h)] \right. \\
& \quad \left. + u_g^{k*}(r, 0) \left[\eta C_{gk}^B u_g^k(r, 0) + (\eta(1 - \beta) - 1) D_g \frac{\partial u_g^k}{\partial z} \Big|_{z=0} \right] \right. \\
& \quad \left. + \frac{\partial u_g^{k*}}{\partial z} \Big|_{z=0} \eta(1 - \beta) [D_g u_g^k(r, h)] \right\} r dr \\
& + \sum_{g=1}^G 2\pi \int_0^h \left\{ u_g^{k*}(R, z) R \left[\theta \gamma C_{gK}^R u_g^k(R, z) + (\theta(\gamma - 1) + 1) D_g \frac{\partial u_g^k}{\partial r} \Big|_{r=R} \right] \right. \\
& \quad \left. + \frac{\partial u_g^{k*}}{\partial r} \Big|_{r=R} R \theta(\gamma - 1) u_g^k(R, z) + \frac{\partial u_g^{k*}}{\partial r} \Big|_{r=0} \frac{\partial u_g^k}{\partial r} \Big|_{r=0} \right\} dz. \quad (\text{Contd.}) \quad (7)
\end{aligned}$$

Varying $u_g^{k*}(r, z)$ and $\alpha_g^k(z)$ arbitrarily in Eq. 7, the following necessary conditions for stationariness are obtained. Writing ϕ_g^k and j_g^k for the stationary values of u_g^k and β_g^k .

$$-\nabla \cdot (D_g \nabla \phi_g^k) + \Sigma_{rg} \phi_g^k - \sum_{g'=1}^{G-1} \Sigma_{g'g} \phi_{g'}^k - \lambda \chi_g \sum_{g'=1}^G (\nu \Sigma_f)_{g'} \phi_{g'}^k = 0, \quad k = 1, \dots, K; \quad (8)$$

$$\varphi_g^{(k+1)}(R_k, z) = \varphi_g^k(R_k, z) \quad (9)$$

$$j_g^k(z) = -D_g \frac{\partial \varphi_g^k}{\partial r} \Big|_{r=R_k} = -D_g \frac{\partial \varphi_g^{(k+1)}}{\partial r} \Big|_{r=R_k} \quad k = 1, \dots, K-1, \quad (10)$$

$$\xi C_{gk}^T \varphi_g^k(r, h) = -\alpha D_g \frac{\partial \varphi_g^k}{\partial z} \Big|_{z=h} \quad k = 1, \dots, K, \quad (11)$$

$$\xi C_{gk}^B \varphi_g^k(r, 0) = +\eta D_g \frac{\partial \varphi_g^k}{\partial z} \Big|_{z=0} \quad k = 1, \dots, K, \quad (12)$$

$$\xi C_{gK}^R \varphi_g^K(R, z) = -\lambda D_g \frac{\partial \varphi_g^K}{\partial r} \Big|_{r=R} \quad (13)$$

and

$$\frac{\partial \varphi_g^1}{\partial r} \Big|_{r=0} = 0, \quad (14)$$

with $g = 1, \dots, G$ in all these equations. The functions φ_g^k and j_g^k thus determined provide the solution to the variational problem posed and at the same time clearly are the functions that give the solution to the neutron-diffusion problem formulated in Eqs. 2 and 4.

Even though the functional J admits discontinuous functions u_g^k with finite jumps at the surfaces with radius R_k , the stationary "point" occurs for functions that are continuous across those boundaries. The Lagrange-multiplier functions $\xi(z)$ turn out to be (see Eq. 10) the values of the normal neutron currents at the boundaries between synthesis regions. Conditions 11, 12, and 13 are the usual conditions of zero incoming current at the reactor boundaries. Condition 14 is a natural condition to require when the flux is symmetric in θ . Equations 11-13 give $\varphi' = 0$, $\varphi = 0$, $D\varphi' + C\varphi = 0$ at the outside as desired.

The actual boundary condition yielded is

$$(\alpha C_{gk}^T + (\lambda - 1) \lambda D_g) \frac{\partial \varphi_g^k}{\partial z} \Big|_{z=h} =$$

instead of Eq. 11. This is, however, equivalent to Eq. 11 for all admissible values of ξ and α . The same comment applies to Eqs. 12 and 13.

To find out the necessary conditions for $u_g^{k*}(r, z)$ and $\alpha_g^k(z)$, the sums in energy in the first summation of Eq. 5 are rearranged in order to take u_g^k as a common factor of the g sums; the following transformation, the symmetric of Eq. 6, is then introduced:

$$\begin{aligned} \sum_{k=1}^K \sum_{g=1}^G \int_{V_k} \nabla u_g^{k*} \cdot D_g \nabla u_g^k r dr dz = & - \sum_{k=1}^K \sum_{g=1}^G \int_{V_k} u_g^k \nabla \cdot (D_g \nabla u_g^{k*}) r dr dz \\ & + \sum_{k=1}^{K-1} \sum_{g=1}^G \left\{ 2\pi R_k \int_0^h \left[u_g^k(R_k, z) D_g \frac{\partial u_g^{k*}}{\partial r} \right]_{r=R_k} \right. \\ & \left. - u_g^{(k+1)}(R_k, z) D_g \frac{\partial u_g^{(k+1)*}}{\partial r} \right|_{r=R_k} dz \Bigg\} \\ & + \sum_{k=1}^K \sum_{g=1}^G \left\{ 2\pi \int_{R_{(k-1)}}^{R_k} \left[u_g^k(r, h) D_g \frac{\partial u_g^{k*}}{\partial z} \right]_{z=h} - u_g^k(r, 0) D_g \frac{\partial u_g^{k*}}{\partial z} \right|_{z=0} r dr \Bigg\} \\ & + 2\pi R \int_0^h \left[u_g^k(R, z) D_g \frac{\partial u_g^{k*}}{\partial r} \right]_{r=R} dz. \end{aligned}$$

The new form of the functional J is

$$\begin{aligned} J = & \sum_{k=1}^K \sum_{g=1}^G 2\pi \int_{V_k} \left\{ u_g^k \left[-\nabla \cdot (D_g \nabla u_g^{k*}) + \Sigma_{rg} u_g^{k*} - \sum_{g'=g+1}^G \Sigma_{gg'} u_g^{k*} \right. \right. \\ & \left. \left. - \lambda (\nabla \Sigma_r)_g \sum_{g'=1}^G \chi_{g'} u_{g'}^{k*} \right] r dr dz + \sum_{k=1}^{K-1} \sum_{g=1}^G 2\pi R_k \int_0^h \left[u_g^{(k+1)*}(R_k, z) \right. \right. \\ & \left. \left. - u_g^k(R_k, z) \right] \beta_g^k - u_g^{(k+1)}(R_k, z) \cdot \alpha_g^k(z) + D_g \frac{\partial u_g^{(k+1)*}}{\partial r} \right|_{r=R_k} \\ & \left. \left(+ u_g^k(R_k, z) \left[\alpha_g^k(z) + D_g \frac{\partial u_g^{k*}}{\partial r} \right]_{r=R_k} \right) \right\} dz \end{aligned} \quad (15)$$

(Contd.)

$$\begin{aligned}
& + \sum_{k=1}^K \sum_{g=1}^G 2\pi \int_{R_{(k-1)}}^{R_k} \left\{ u_g^k(r, h) \left\{ \alpha C_{gk}^T u_g^{k*}(r, h) + [\zeta(\alpha - 1) + 1] D_g \frac{\partial u_g^{k*}}{\partial z} \right\} \right. \\
& + \left. \frac{\partial u_g^k}{\partial z} \right|_{z=h} \left\{ \zeta(\alpha - 1) D_g u_g^{k*}(r, h) + u_g^k(r, 0) \left\{ \beta \gamma C_{gk}^B u_g^{k*}(r, 0) \right. \right. \\
& + \left. \left. [\eta(1 - \beta) + 1] D_g \frac{\partial u_g^{k*}}{\partial z} \right|_{z=0} \right\} - \left. \frac{\partial u_g^k}{\partial z} \right|_{z=0} \eta(1 - \beta) D_g u_g^{k*}(r, h) \right\} r dr \\
& + \sum_{g=1}^G 2\pi \int_0^h \left\{ u_g^K(R, z) R \left\{ \theta \gamma C_{gk}^R u_g^{K*}(R, z) + [\theta(\gamma - 1) + 1] D_g \frac{\partial u_g^{K*}}{\partial r} \right\} \right. \\
& + \left. \frac{\partial u_g^K}{\partial r} \right|_{r=R} R - \theta(\gamma - 1) u_g^{K*}(R, z) + \left. \frac{\partial u_g^K}{\partial r} \right|_{r=0} \frac{\partial u_g^K}{\partial r} \bigg|_{r=0} \right\} dz. \quad (\text{Contd.}) \quad (15)
\end{aligned}$$

If $u_g^k(r, z)$ and $\varphi_g^k(z)$ in Eq 15 are arbitrarily varied, the following necessary conditions for stationariness follow:

$$-\nabla \cdot (D_g \nabla \varphi_g^{k*}) + \Sigma_g \varphi_g^{k*} - \sum_{g'=1}^G \Sigma_{gg'} \varphi_{g'}^{k*} - \lambda (\nu \Sigma_f)_g \sum_{g'=1}^G \chi_{g'} \varphi_{g'}^{k*} = 0,$$

$$k = 1, \dots, K; \quad (16)$$

$$\varphi_g^{(k+1)*}(R_k, z) = \varphi_g^{k*}(R_k, z) \quad (17)$$

$$\left. \begin{aligned} \varphi_g^{k*}(z) &= D_g \frac{\partial \varphi_g^{(k+1)*}}{\partial r} \bigg|_{r=R_k} \\ &- D_g \frac{\partial \varphi_g^{k*}}{\partial r} \bigg|_{r=R_k} \end{aligned} \right\}, \quad k = 1, \dots, K-1, \quad (18)$$

$$C_{gk}^R \varphi_g^{k*}(r, h) = -\alpha D_g \frac{\partial \varphi_g^{k*}}{\partial z} \bigg|_{z=h} \quad (19)$$

$$\eta C_{gk}^B \varphi_g^{k*}(r, 0) = +\beta D_g \frac{\partial \varphi_g^{k*}}{\partial z} \bigg|_{z=0} \quad (20)$$

$$\partial C_{gk}^R \varphi_g^{K*}(R, z) = -\gamma D_g \left. \frac{\partial \varphi_g^{K*}}{\partial r} \right|_{r=R} \quad (21)$$

and

$$\left. \frac{\partial \varphi_g^{1*}}{\partial r} \right|_{r=0} = 0, \quad (22)$$

with $g = 1, \dots, G$ in all these equations

These sets of equations and conditions satisfy both the variational condition required and the adjoint diffusion Eqs 3 and 4

3. The Synthesis Assumptions and the Synthesis Equations

The following synthesis assumptions are now introduced

$$u_g^k(r, z) = \sum_{n=1}^{N_g^k} H_{gn}^k(z) T_{gn}^k(r) \quad \left. \begin{array}{l} k = 1, \dots, K; \\ g = 1, \dots, G. \end{array} \right\} \quad (23)$$

$$u_g^{k*}(r, z) = \sum_{n=1}^{N_g^k} H_{gn}^{k*}(z) T_{gn}^{k*}(r) \quad (24)$$

Here $H_{gn}^k(z)$ and $H_{gn}^{k*}(z)$, usually referred to as the trial functions, are known functions. The functions $T_{gn}^k(r)$ and $T_{gn}^{k*}(r)$ are unknown functions to be determined. The numbers N_g^k of trial functions at each group and region do not have intrinsic limitations except the obvious one, $N_g^k \geq 1$. The functions $\beta_g^k(z)$ and $\alpha_g^k(z)$ are also expanded

$$\beta_g^k(z) = \sum_{n=1}^{M_g^k} B_{gn}^k(z) b_{gn}^k \quad (25)$$

$$k = 1, \dots, K-1$$

$$g = 1, \dots, G$$

$$\alpha_g^k(z) = \sum_{n=1}^{M_g^k} A_{gn}^k(z) a_{gn}^k \quad (26)$$

Here the mixing coefficients a_{gn}^k and b_{gn}^k are pure numbers. The numbers M_g^k of trial functions for the normal currents at the interfaces have upper and lower bounds, as will be shown later (see Eq. 47).

The selection of trial functions $H_{gn}^k(z)$, $H_{gn}^{k*}(z)$ and $B_{gn}^k(z)$, $A_{gn}^k(z)$ has to be guided by whatever knowledge or intuition the user of the method has about the system to be calculated. The variational method, or any other similar method, can only combine these preselected flux shapes in some optimum way, but it will never achieve a good approximation to the actual fluxes of the system with a poor selection of trial functions.

From the variational point of view, assumptions 23-26 mean that the freedom of choice of independent-variable functions for functional 5 is now restricted to functions of the form given in those expansions. The problem is now restricted to finding functions with the forms of Eqs. 23-26 that will make stationary the value of the functional 5

A variational problem like the one posed in connection with the functional in 5 is defined both by the functional used and by the set of admissible functions used with it. We are thus now treating a different variational problem from the initial one, because the set of admissible functions is severely restricted by the synthesis assumption

The functional J' obtained by substituting the synthesis assumptions (Eqs. 23-26) into Eq. 5 is called the "reduced" functional. Its independent variable functions are now $T_{gn}^k(r)$, $T_{gn}^{k*}(r)$, a_{gn}^k and b_{gn}^k . The corresponding necessary conditions for a stationary value, its Euler equations, are also of a lower dimensionality.

The functional J' is

$$\begin{aligned}
 J' [T_{gn}^k(r), T_{gn}^{k*}(r), b_{gn}^k, a_{gn}^k] = & \sum_{g=1}^G \left\langle \sum_{k=1}^K \int_{R_{(k-1)}}^{R_k} z^{-\gamma} r^{\gamma} dr \left(\frac{dT_g^k}{dr} [D_g^k] \frac{dT_g^{k*}}{dr} \right. \right. \\
 & + \bar{T}_g^{k*} \left\{ [L_g^k] + [E_g^k] + [C_g^k] \right\} \bar{T}_g^k - \sum_{g'=1}^{g-1} \bar{T}_g^{k*} [T_{g',g}^k] \bar{T}_g^k \\
 & + \lambda \sum_{g=1}^G \bar{T}_g^{k*} \left([x_{gk} \gamma E_{f,g}^k] \bar{T}_g^k \right) \Bigg\rangle + \sum_{g=1}^G \left\langle \sum_{k=1}^{K-1} \left[z^{-\gamma} R_k a_g^k \left\{ [A_g^k] \bar{T}_g^k(R_k) \right. \right. \right. \\
 & + \left. \left. [\bar{A}_g^{(k+1)}] \bar{T}_g^{(k+1)}(R_k) \right\} + \left\{ \bar{T}_g^k(R_k) [B_g^k] - \bar{T}_g^{(k+1)}(R_k) [\bar{B}_g^{(k+1)}] \right\} \bar{E}_g^k \right] z^{-\gamma} R_k \right. \\
 & + \left. z^{-\gamma} \left\{ \theta_{\gamma} C_{gK} R \bar{T}_g^{K*}(R) [W] \bar{T}_g^K(R) + \frac{dT_g^{1*}}{dr} \Big|_{r=0} [W^1] \frac{dT_g^1}{dr} \Big|_{r=0} \right. \right. \\
 & \left. \left. + R \theta (\gamma-1) \left[\bar{T}_g^{K*} [D_g^K] \frac{dT_g^K}{dr} \Big|_{r=R} + \bar{T}_g^K [D_g^K] \frac{dT_g^{K*}}{dr} \Big|_{r=R} \right] \right\rangle \quad (27)
 \end{aligned}$$

where the following nomenclature has been adopted: $\bar{T}_g^k$ and $\bar{b}_g^k$ are column vectors with components $T_{gn}^k(r)$ and b_{gn}^k , $\bar{T}_g^{k*}$ and $\bar{a}_g^k$ are row vectors with components $T_{gm}^{k*}(r)$ and a_{gm}^k . Left multiplication on a matrix implies a row vector, right multiplication a column vector.

$[D_g^k]$ is an N_g^k by N_g^k square matrix with elements defined by

$$\int_0^h D_g(r, z) H_{gm}^{k*}(z) H_{gn}^k(z) dz = D_{gk}^{mn}(r), \quad (28)$$

$[L_g^k]$ is an N_g^k by N_g^k square matrix with elements defined by

$$L_{gk}^{mn}(r) = \int_0^h D_g(r, z) \frac{dH_{gm}^{k*}(z)}{dz} \frac{dH_{gn}^k(z)}{dz} dz; \quad (29)$$

$[\Sigma_g^k]$ is an N_g^k by N_g^k square matrix with elements defined by

$$\int_0^h \Sigma_{rg}(r, z) H_{gm}^{k*}(z) H_{gn}^k(z) dz = \Sigma_{gk}^{mn}(r); \quad (30)$$

$[C_g^k]$ is an N_g^k by N_g^k square matrix with elements defined by

$$\begin{aligned} & \left\{ \alpha C_{gk}^T H_{gm}^{k*}(h) H_{gn}^k(h) + (\alpha - 1) D_g(r, h) \left[H_{gm}^{k*}(h) H_{gn}^{k'} \Big|_{z=h} + H_{gm}^{k*'} \Big|_{z=h} H_{gn}^k(h) \right] \right\} \\ & + \eta \left\{ \beta C_{gk}^B H_{gm}^{k*}(0) H_{gn}^k(0) + (1 - \beta) D_g(r, 0) \left[H_{gm}^{k*}(0) H_{gn}^{k'} \Big|_{z=0} \right. \right. \\ & \left. \left. + H_{gm}^{k*'} \Big|_{z=0} H_{gn}^k(0) \right] \right\} = C_{gk}^{mn}(r). \end{aligned} \quad (31)$$

$[\Sigma_{g,g}^k]$ is an N_g^k by N_g^k rectangular matrix with elements defined by

$$\int_0^h \Sigma_{g,g}(r, z) H_{gm}^{k*}(z) H_{gn}^k(z) dz = \Sigma_{g,g,k}^{mn}(r); \quad (32)$$

$\{[\chi_g(v\Sigma_f)_g]^k\}$ is an N_g^k by N_g^k rectangular matrix with elements defined by

$$\int_0^h (\chi_g v_g \Sigma_{fg})(r, z) H_{gm}^{k*}(z) H_{gn}^k(z) dz = (\chi_g v_g \Sigma_{fg})_k^{mn}(r), \quad (33)$$

$[W_g^k]$ is an N_g^k by N_g^k square matrix with elements defined by

$$\int_0^h H_{gm}^{k*}(z) H_{gn}^k(z) dz = W_{gk}^{mn}, \quad k = 1 \text{ and } K; \quad (34)$$

$[A_g^k]$ is an M_g^k by N_g^k rectangular matrix, and $[\bar{A}_g^{(k+1)}]$ is an M_g^k by $N_g^{(k+1)}$ rectangular matrix with elements defined by

$$\int_0^h A_{gm}^k(z) H_{gn}^k(z) dz = A_{gk}^{mn} \quad (35)$$

and

$$\int_0^h A_{gm}^k(z) H_{gn}^{(k+1)}(z) dz = \bar{A}_{g(k+1)}^{mn}, \text{ respectively; } \quad (36)$$

$[B_g^k]$ is an N_g^k by M_g^k rectangular matrix, and $[\bar{B}_g^{(k+1)}]$ is an $N_g^{(k+1)}$ by M_g^k rectangular matrix with elements defined by

$$\int_0^h H_{gm}^{k*}(z) B_{gn}^k(z) dz = B_{gk}^{mn} \quad (37)$$

and

$$\int_0^h H_{gm}^{(k+1)*}(z) B_{gn}^k(z) dz = \bar{B}_{g(k+1)}^{mn}, \text{ respectively. } \quad (38)$$

To obtain the Euler equations in $\bar{T}_{gn}^k(r)$ and $\bar{p}_{gn}^k$ for this functional, it is convenient to transform Eq. 27 by integrating the double-gradient term by parts:

$$\begin{aligned}
\sum_{g=1}^G \sum_{k=1}^K \int_{R_{(k-1)}}^{R_k} 2\pi r dr \frac{d\bar{T}_g^{k*}}{dr} [D_g^k] \frac{d\bar{T}_g^k}{dr} &= \sum_{g=1}^G \left\langle \sum_{k=1}^K \int_{R_{(k-1)}}^{R_k} \right. \\
&- 2\pi \bar{T}_g^{k*} \frac{d}{dr} \left\{ r [D_g^k] \frac{d\bar{T}_g^k}{dr} \right\} dr + \sum_{k=1}^{K-1} 2\pi R_k \left\{ \bar{T}_g^{k*}(R_k) [D_g^k] \frac{d\bar{T}_g^k}{dr} \right\}_{r=R_k} \\
&- \left. \bar{T}_g^{(k+1)*}(R_k) [D_g^{(k+1)}] \frac{d\bar{T}_g^{(k+1)}}{dr} \right\}_{r=R_k} \left. \right\rangle + 2\pi R \bar{T}_g^{K*}(R) [D_g^K] \frac{d\bar{T}_g^K}{dr} \bigg|_{r=R} \quad (3)
\end{aligned}$$

Introducing Eq. 39 into Eq. 27 results in

$$\begin{aligned}
J' &= \sum_{g=1}^G \left[\sum_{k=1}^K \left\langle \int_{R_{(k-1)}}^{R_k} 2\pi r dr \bar{T}_g^{k*} \left(-\frac{1}{r} \frac{d}{dr} \left[r [D_g^k] \frac{d\bar{T}_g^k}{dr} \right] + \left\{ [L_g^k] + [r_g^k] + [C_g^k] \right\} \bar{T}_g^k \right. \right. \right. \\
&- \left. \left. \sum_{g'=1}^{g-1} [T_{g'g}^k] \bar{T}_g^k + \lambda \sum_{g'=1}^G \{ x_{g'}(\sqrt{\epsilon_f})_{g'} \}^k \bar{T}_g^k \right\rangle \right. \\
&+ \left. \sum_{k=1}^{K-1} \left\langle 2\pi R_k \bar{a}_g^{k*} \left\{ [A_g^k] \bar{T}_g^k(R_k) - [\bar{A}_g^{(k+1)}] \bar{T}_g^{(k+1)}(R_k) \right\} \right. \right. \\
&+ \left. \left. 2\pi R_k \bar{T}_g^{k*}(R_k) \left\{ [D_g^k] \frac{d\bar{T}_g^k}{dr} \bigg|_{r=R_k} + [b_g^k] \bar{b}_g^k \right\} \right. \right. \\
&- \left. \left. 2\pi R_k \bar{T}_g^{(k+1)*}(R_k) \left\{ [D_g^{(k+1)}] \frac{d\bar{T}_g^{(k+1)}}{dr} \bigg|_{r=R_k} + [\bar{B}_g^{(k+1)}] \bar{b}_g^k \right\} \right. \right. \\
&+ \left. \left. 2\pi R \theta(\gamma-1) \left[\bar{T}_g^{K*} [D_g^K] \frac{d\bar{T}_g^K}{dr} \bigg|_{r=R} + \bar{T}_g^K [D_g^K] \frac{d\bar{T}_g^{K*}}{dr} \bigg|_{r=R} \right] \right. \\
&+ \left. \left. 2\pi R \bar{T}_g^{K*}(R) \left\{ \gamma \theta C_{gK}^R [W_g^K] \bar{T}_g^K + [D_g^K] \frac{d\bar{T}_g^K}{dr} \bigg|_{r=R} \right\} \right. \right. \\
&+ \left. \left. \frac{d\bar{T}_g^{1*}}{dr} \bigg|_{r=0} 2\pi [w_g^1] \frac{d\bar{T}_g^1}{dr} \bigg|_{r=0} \right] \quad (40)
\end{aligned}$$

And now an arbitrary variation of the independent variable-functions $T_{gm}^{k*}(r)$ and a_{gm}^k yields immediately the following conditions for stationariness for $T_{gn}^k(r)$ and b_{gn}^k , now named i_{gn}^k and j_{gn}^k . In the volumes V_k ,

$$\sum_{n=1}^{N_g^k} \left[\frac{d}{dr} \left(r D_{gk}^{mn} \frac{d\psi_{gn}^k}{dr} \right) + r \left(L_{gk}^{mn} + \Sigma_{gk}^{mn} + C_{gk}^{mn} \right) \psi_{gn}^k \right] - \sum_{n=1}^{N_g^k} \left(\sum_{g'=1}^{G-1} r \Sigma_{g'gk}^{mn} \psi_{g'n}^k \right) + \lambda \sum_{g=1}^G r \left\{ \left[\chi_g(w \Sigma_f) \right]_{gk}^{mn} \right\} \psi_{gn}^k = 0, \quad m = 1, 2, \dots, N_g^k, k = 1, 2, \dots, K; \quad (41)$$

at the cylindrical surfaces with radius R_k ,

$$\sum_{n=1}^{N_g^k} A_{gk}^{mn} \psi_{gn}^k(R_k) = \sum_{n=1}^{N_{g(k+1)}^k} \bar{A}_{g(k+1)}^{mn} \psi_{gn}^{(k+1)}(R_k), \quad m = 1, 2, \dots, M_g^k; \quad (42)$$

$$\sum_{n=1}^{N_g^k} D_{gk}^{mn}(R_k) \frac{d\psi_{gn}^k}{dr} \Big|_{r=R_k} + \sum_{n=1}^{M_g^k} B_{gk}^{mn} \psi_{gn}^k = 0, \quad m = 1, 2, \dots, N_g^k; \quad (43)$$

$$\sum_{n=1}^{N_{g(k+1)}^k} D_{g(k+1)}^{mn}(R_k) \frac{d\psi_{gn}^{(k+1)}}{dr} \Big|_{r=R_k} + \sum_{n=1}^{M_g^k} \bar{B}_{g(k+1)}^{mn} \psi_{gn}^k = 0, \quad m = 1, 2, \dots, N_{g(k+1)}^k; \quad (44)$$

at the outer surface of the reactor,

$$\sum_{n=1}^{N_g^K} \left\{ \gamma D_{gK}^{mn}(R) \frac{d\psi_{gn}^K}{dr} \Big|_{r=R} + \theta C_{gK}^R w_{gK}^{mn} \psi_{gn}^K(R) \right\} = 0, \quad m = 1, \dots, N_g^K; \quad (45)$$

at $r = 0$,

$$\sum_{n=1}^{N_g^1} \left\{ w_{g1}^{mn} \frac{d\psi_{gn}^1}{dr} \Big|_{r=0} \right\} = 0, \quad m = 1, 2, \dots, N_g^1; \quad (46)$$

and $g = 1, 2, \dots, G$ in Eqs. 41-4

† Actually Eq. 45 is only technically correct. The possible boundary conditions at $r = R$ are $\theta = 0$, $\gamma = 1$, im-

plying $\left[D_{gK}^K \right] \frac{d\psi_{gK}^K}{dr} \Big|_{r=R} = 0$, which in turn implies that $\frac{d\psi_{gK}^K}{dr} \Big|_{r=R} = 0$ since, as we will show later, $\left[D_{gK}^K \right]^{-1}$ and

$\left[w_{gK}^K \right]^{-1}$ exist; $\theta = 1$, $\gamma = 0$, implying $\left[D_{gK}^K \right] \frac{d\psi_{gK}^K}{dr} \Big|_{r=R} = 0$, which in turn implies that $\psi_{gK}^K \Big|_{r=R} = 0$. Finally,

$\theta = 1$, $\gamma = 1$, implying $\left[D_{gK}^K \right] \frac{d\psi_{gK}^K}{dr} \Big|_{r=R} + C_{gK}^R \psi_{gK}^K = 0$. Eq. 45 with proper manipulation will yield this.

The systems of Eqs. 41-46 form a well-determined systems of equations with an equal number of unknowns and conditions. From the physical point of view, though, it is necessary to impose bounds on the numbers M_g^k of trial functions B_{gn}^k and A_{gn}^k . From the structure of the conditions, Eqs. 42-46, it is clearly necessary that

$$1 \leq M_g^k \leq N_g^k + N_g^{k+1} \quad (47)$$

if one is to avoid zero values for the fluxes and adjoints at the interface.

Finally, the approximate values of fluxes and currents are obtained by substituting the solutions $\psi_{gn}^k(r)$ and j_{gn}^k of this system of differential equations into Eqs. 23 and 25. The finite-difference approximation (Section 4) to the system of Eqs. 41 with boundary and interface conditions (Eqs. 42-46), along with the additional assumptions

$$B_{gn}^k(z) = D_g^k(R_k, z) H_{gn}^k(z) \quad (48)$$

and

$$A_{gn}^k(z) = D_g^k(R_k, z) H_{gn}^{k*}(z) \quad (49)$$

is solved by SYN2D. These assumptions (Eqs. 48 and 49) reduce the choice of trial functions to those for the fluxes and adjoints, that is, the $H_{gn}^k(z)$ and $H_{gn}^{k*}(z)$, eliminating the need for special expansion functions for the currents. They constitute an asymmetric weighting at the interfaces, as the weight functions are those corresponding to one side of the interface.

It is possible to establish a set of symmetric interface conditions instead of the set (Eqs. 42-44) [with assumptions (Eqs. 48 and 49)], by weighted residual methods as follows:

The desired condition at the boundary between synthesis regions k and $k+1$ are the equality of fluxes and the equality of currents. Using the approximations (Eqs. 2 and 24), we cannot exactly satisfy these equalities. In general, each one is satisfied to within an error, called residual

$$\sum_{n=1}^{N_g} H_{gn}^k(z) \psi_{gn}^k(R_k) - \sum_{n=1}^{N_g} H_{gn}^{(k+1)}(z) \psi_{gn}^{(k+1)}(R_k) = e_1(z) \quad (50)$$

and

$$\sum_{n=1}^{N_g} D_g(R_k, z) H_{gn}^k(z) \frac{d\psi_{gn}^k}{dr} \Big|_{r=R_k} - \sum_{n=1}^{N_g} D_g(R_k, z) H_{gn}^{(k+1)}(z) \frac{d\psi_{gn}^{(k+1)}}{dr} \Big|_{r=R_k} = e_2(z) \quad (51)$$

One now proceeds to weight these residuals with some weight function and to equate the weighted residuals to zero. To obtain a well-posed problem, one has to create in this case $2N_g$ weighted residual conditions. The weight functions to be used are

$$X_{gm}^{k*}(z) \equiv H_{gm}^{k*}(z) + H_{gm}^{(k+1)*}(z), \quad m = 1, \dots, N_g \quad (52)$$

and the weighted residual interface conditions obtained are

$$\sum_{n=1}^{N_g} \left[\hat{V}_{gk}^{mn} \psi_{gn}^k(R_k) - \hat{W}_{g(k+1)}^{mn} \psi_{gn}^{(k+1)}(R_k) \right] = 0, \quad (53)$$

and

$$\sum_{n=1}^{N_g} \hat{K}_{gk}^{mn}(R_k) \frac{d\psi_{gn}^k}{dr} \Big|_{r=R_k} - \hat{L}_{g(k+1)}^{mn}(R_k) \frac{d\psi_{gn}^{(k+1)}}{dr} \Big|_{r=R_k} = 0, \quad m = 1, \dots, N_g, \quad (54)$$

where

$$\hat{V}_{gk}^{mn} = \int_0^h X_{gm}^{k*}(z) H_{gn}^k(z) dz, \quad (55)$$

$$\hat{W}_{g(k+1)}^{mn} = \int_0^h X_{gm}^{k*}(z) H_{gn}^{(k+1)}(z) dz, \quad (56)$$

$$\hat{K}_{gk}^{mn}(R_k) = \int_0^h D_g(R_k, z) X_{gm}^{k*}(z) H_{gn}^k(z) dz, \quad (57)$$

and

$$\hat{L}_{g(k+1)}^{mn}(R_k) = \int_0^h D_g(R_k, z) X_{gm}^{k*}(z) H_{gn}^{(k+1)}(z) dz. \quad (58)$$

The $2N_g$ interface conditions (Eqs. 53 and 54), together with the equations and conditions (Eqs. 41, 45, and 46), form a well-posed system of differential equations. In this weighted residual option of the interface conditions, the essential restriction $N_k^g = N_g^{(k+1)}$ for all k has been implicit. These symmetric weighted residual interface conditions have also been programmed in SYN2D as an alternative option.

4. Discrete Approximations and Method of Solution

Rewriting synthesis Eqs 41-46 in matrix form, using definitions 28-38, we obtain

$$-\frac{1}{r} \frac{d}{dr} r [D_g^k] \frac{d\bar{\psi}_g^k}{dr} + [\Sigma_{Rg}^k] \bar{\psi}_g^k = \sum_{g'=1}^{G-1} [\Sigma_{gg'}^k] \bar{\psi}_{g'}^k + \lambda \sum_{g'=1}^G \left\{ [\chi_g(v\Sigma_f)_{g'}] \right\} \bar{\psi}_{g'}^k \quad (59)$$

with interface and boundary conditions

$$[A_g^k] \bar{\psi}_g^k(R_k) = [\bar{A}_g^{(k+1)}] \bar{\psi}_g^{(k+1)}(R_k) \quad (60)$$

$$[D_g^k(R_k)] \frac{d\bar{\psi}_g^k}{dr} \Big|_{r=R_k} + [B_g^k] \bar{\psi}_g^k = 0, \quad (61)$$

$$[D_g^{(k+1)}(R_k)] \frac{d\bar{\psi}_g^{(k+1)}}{dr} \Big|_{r=R_k} + [\bar{B}_g^{(k+1)}] \bar{\psi}_g^k = 0, \quad (62)$$

and

$$v [D_g^K(R)] \frac{d\bar{\psi}_g^K}{dr} \Big|_{r=R} + \theta C_{gK}^R [W_g^K] \bar{\psi}_g^K(R) = 0, \quad (63)$$

with $k = 1, 2, \dots, K$, and $g = 1, 2, \dots, G$. $\bar{\psi}_g^k$ and $\bar{j}_g^k$ are column vectors with components ψ_{gn}^k and j_{gn}^k , respectively, and

$$[\Sigma_{Rg}^k] \equiv [L_g^k] + [\Sigma_g^k] + [C_g^k] \quad (64)$$

With this notation it is seen that the system has the form of the usual one-dimensional multigroup equation where matrices now replace the usual scalar coefficients. This observation forms the basis for the derivation of a finite-difference approximation to the given system. Since most of the derivations involved with the Laplacian term, it will suffice to consider the case of one group. Thus the group index is dropped.

Let the reactor domain be the interval $[0, R]$, and impose a mesh $0 = \rho_0 < \rho_1 < \dots < \rho_I = R$ on this interval in such a manner that

- a. Any synthesis interface coincides with some mesh point ρ_i .
- b. Any region interface coincides with some mesh point ρ_i .

Then in any interval $[\rho_{i-1}, \rho_i]$ we can assume that we have a differential system of the form

$$-\frac{1}{r} \frac{d}{dr} \left(r D_1 \frac{d\psi}{dr} \right) + (\Sigma_R)_i \psi = f_i(r) \quad (65)$$

with interface conditions

$$A_{i-1} \psi(\rho_{i-1}^-) = \hat{A}_{i-1} \psi(\rho_{i-1}^+),$$

$$A_i \psi(\rho_i^-) = \hat{A}_i \psi(\rho_i^+),$$

$$D_{i-1} \psi'(\rho_{i-1}^-) + B_{i-1} \psi(\rho_{i-1}^-) = 0,$$

$$\hat{D}_{i-1} \psi'(\rho_{i-1}^+) + \hat{B}_{i-1} \psi(\rho_{i-1}^+) = 0,$$

$$D_i \psi'(\rho_i^-) + B_i \psi(\rho_i^-) = 0,$$

and

$$\hat{D}_i \psi'(\rho_i^+) + \hat{B}_i \psi(\rho_i^+) = 0,$$

where the vector and matrix notation has been dropped for simplicity. The relation between A_i and $\hat{A}_i$, B_i and $\hat{B}_i$, D_i and $\hat{D}_i$ is the same as that which exists between $[A_g^k]$ and $[\hat{A}_g^{k+1}]$, $[B_g^k]$ and $[\hat{B}_g^{k+1}]$, and $[D_g^k(R_k)]$ and $[D_g^{(k+1)}(R_k)]$, where i now indicates mesh point ρ_i ; ρ_i^- and ρ_i^+ indicate evaluation at point ρ_i using functions defined to the left or right of the point respectively; ψ' indicates derivative with respect to r . The dimension of $\psi(r)$ is N_i , where $N_i = N_k$ when the interval $[\rho_{i-1}, \rho_i]$ lies in the k th synthesis region. Since each interval lies entirely within a region of constant composition, the coefficient matrices are constant over each interval. If ρ_i is a regular interface point in the sense that it does not separate two synthesis regions, then the dimension of $\psi(r)$ does not change when passing from $[\rho_{i-1}, \rho_i]$ to $[\rho_i, \rho_{i+1}]$. In this case, the interface conditions are defined by the matrix relationships

$$A_i = \hat{A}_i = I; \quad N_i \times N_i;$$

$$B_i = \hat{B}_i = I; \quad N_i \times N_i.$$

On the other hand, if ρ_i separates the k th synthesis region from the $(k+1)$ st, then the interface matrices are defined by

$$A_i = A_k; \quad M_i \times N_i, \quad M_i = M_k, \quad N_i = N_k;$$

$$\hat{A}_i = \hat{A}_{k+1}; \quad M_i \times N_{i+1}, \quad N_{i+1} = N_{k+1};$$

$$B_i = B_k; \quad N_i \times M_i;$$

$$\hat{B}_i = \hat{B}_{k+1}; \quad N_{i+1} \times M_i.$$

To derive a finite-difference approximation, consider the following class of functions defined on the interval $[r_i, r_{i+1}]$, where r_i is the midpoint of the interval $[\rho_{i-1}, \rho_i]$.

$$\psi(r) = \begin{cases} \psi(r_i) + (r - r_i) \zeta, & r_i \leq r \leq \rho_i, \\ \psi(r_{i+1}) - (r_{i+1} - r) \xi, & \rho_i \leq r \leq r_{i+1}, \end{cases}$$

which satisfy the conditions

$$A_i \psi(\rho_i^-) = \hat{A}_i \psi(\rho_i^+),$$

$$D_i \psi'(\rho_i^-) + B_{ij} j_i = 0,$$

and

$$\hat{D}_i \psi'(\rho_i^+) + \hat{B}_{ij} j_i = 0$$

Here ζ , ξ , and j_i are assumed to be given vectors having dimensions N_i , N_{i+1} , and M_i , respectively.

If the interface conditions are applied to this class of functions, ζ , ξ , and j_i must satisfy the following system of equations:

$$\frac{1}{2} \delta_i A_i \zeta + \frac{1}{2} \delta_{i+1} \hat{A}_i \xi = \hat{A}_i \psi(r_{i+1}) - A_i \psi(r_i),$$

$$D_i \zeta + B_{ij} j_i = 0,$$

and

$$\hat{D}_i \xi + \hat{B}_{ij} j_i = 0,$$

where δ_i denotes the length of the interval $[\rho_{i-1}, \rho_i]$.

Up to this point, no assumptions have been made concerning the nature or structure of the matrices A_i , $\hat{A}_i$, D_i , $\hat{D}_i$, B_{ij} , and $\hat{B}_{ij}$; thus the question of existence of a solution to the above system is still open. In fact, the matter is not trivial, even in the case of a regular interface. In this case, the system reduces to the following system by eliminating the vector j_i :

$$\frac{1}{2} \delta_i \zeta + \frac{1}{2} \delta_{i+1} \xi = \psi(r_{i+1}) - \psi(r_i),$$

$$-D_i \zeta + \hat{D}_i \xi = 0.$$

This leads to the equation

$$[\frac{1}{2} \delta_i D_i + \frac{1}{2} \delta_{i+1} \hat{D}_i] \xi = D_i [\psi(r_{i+1}) - \psi(r_i)].$$

The question now arises whether the matrix

$$A_1 = \frac{1}{2} \delta_1 \bar{D}_1 + \frac{1}{2} \delta_{1+1} D_1$$

is invertible. If it is, then

$$D_{1g} = \bar{D}_{1g} = \bar{D}_1 A_1^{-1} D_1 [\psi(r_{1+1}) - \psi(r_1)].$$

The question of nonsingularity, although easy to characterize in terms of cross-grammians, is not easy to characterize in more physical terms. Thus, for example, consider the question of whether or not the matrix D_1 is singular. Recall that these matrices have elements D^{mn} defined by

$$D^{mn} = \sum_{j=1}^J w_j H_m^*(j) H_n(j), \quad 1 \leq m, n \leq N.$$

Here we have dropped the i subscript since it is not pertinent. The weights w_j result from numerically approximating the corresponding integral, moreover, $H_m^*(j)$ and $H_n(j)$ are the numerical values of the trial functions. Define the vectors

$$H_m^* = \{H_m^*(j)\}_{j=1}^J \quad \text{and} \quad H_n = \{H_n(j)\}_{j=1}^J$$

for $n = 1, 2, \dots, N$. Let X be the J -dimensional Hilbert space defined by the inner product

$$\langle X, Y \rangle = \sum_{j=1}^J w_j X_j Y_j$$

Then in this space X we are given two sets of vectors $\{H_1, H_2, \dots, H_N\}$ and $\{H_1^*, H_2^*, \dots, H_N^*\}$, each set being linearly independent. The matrix D is then the cross-grammian of these two sets of vectors. Let M denote the subspace generated by the set $\{H_n\}$ and N denote the subspace generated by the set $\{H_m^*\}$; then the matrix D is singular if M and $N^\perp$ are disjoint. Note that since M and N have the same dimension, this last statement is equivalent to the statement that M and $N^\perp$ span the space X . Also note that if $\{H_m^*\}$ is the conjugate set of $\{H_n\}$, then $M = N$ and it is clear that the matrix D is nonsingular and indeed it is a diagonal matrix in this case. This observation leads to the following result: The matrix D , which is the cross-grammian for the two sets of vectors, is nonsingular if, and only if, the two sets of vectors span the same space.

If the cross-grammian is nonsingular, then a conjugate set for the set $\{H_n\}$ can be constructed from the set $\{H_m\}$. But the conjugate set for $\{H_n\}$ spans the same space as $\{H_n\}$, hence $\{H_m^*\}$ also spans the same space. On the other hand, if the two sets of vectors span the same space, and if the cross-grammian were singular, there would exist a nonzero element in the space which was orthogonal to every element of the set $\{H_n\}$. This would contradict the fact that the space was generated by the linearly independent set $\{H_n\}$.

Although it is not hard to state criteria for the matrix D to be nonsingular, it is very difficult to give simple heuristic criteria by which the user can be guided in choosing trial functions.

Returning to the general system for ξ , ζ , and J_1 , we find that if D_1 and $\hat{D}_1$ are nonsingular, then

$$\xi = D_1^{-1} B_1 J_1$$

$$\xi = \hat{D}_1^{-1} \hat{B}_1 J_1$$

and

$$\left(\frac{1}{2} \delta_1 A_1 D_1^{-1} B_1 + \frac{1}{2} \delta_{1+1} \hat{A}_1 \hat{D}_1^{-1} \hat{B}_1 \right) J_1 = \hat{A}_1 \psi(r_{1+1}) - A_1 \psi(r_1).$$

If the $M_1 \times M_1$ dimensional matrix

$$\Omega_1 = \frac{1}{2} \delta_1 A_1 D_1^{-1} B_1 + \frac{1}{2} \delta_{1+1} \hat{A}_1 \hat{D}_1^{-1} \hat{B}_1$$

has an inverse, then

$$D_1 \xi = B_1 \Omega_1^{-1} [\hat{A}_1 \psi(r_{1+1}) - A_1 \psi(r_1)],$$

and

$$\hat{D}_1 \xi = \hat{B}_1 \hat{\Omega}_1^{-1} [\hat{A}_1 \psi(r_{1+1}) - A_1 \psi(r_1)].$$

With the assumption of invertibility, $\psi(r)$ has now been determined as a class of piecewise linear vector-valued functions which satisfy the given interface conditions.

Returning to the differential Eq. 65 and integrating it with respect to r over the interval $[p_{i-1}, p_i]$ leads to the equation

$$- [p_i D_1 \psi'(p_i) - p_{i-1} D_1 \psi'(p_{i-1})] + (\Sigma R)_i \int_{p_{i-1}}^{p_i} \psi(r) r dr = \int_{p_{i-1}}^{p_i} f_i(r) r dr.$$

$$1 \leq i \leq I$$

(66)

The solution to this system within the class of functions just constructed is required. Using the expressions for $D_1 \psi'(p_1)$ and $D_1 \psi'(p_{1-1})$ just derived, we obtain the system

$$\begin{aligned} & -\{D_1 B_1 \Omega_1^{-1} [\hat{A}_1 \psi(r_{1+1}) - A_1 \psi(r_1)] - p_{1-1} \hat{B}_{1-1} \Omega_{1-1}^{-1} [\hat{A}_{1-1} \psi(r_1) - A_{1-1} \psi(r_{1-1})]\} \\ & + \{E_1\}_1 \int_{p_{1-1}}^{p_1} \psi(r) r dr = \int_{p_{1-1}}^{p_1} f_1(r) r dr \end{aligned} \quad (67)$$

Integrating the functions in this class would result in a quadrature formula linking $\psi(r_{1-1})$, $\psi(r_1)$, and $\psi(r_{1+1})$. However, the truncation error is of a higher order than that which results from the derivative terms. In addition, such a quadrature formula leads to nonsymmetric matrices, even in the case of regular interface conditions. For these reasons, the following quadrature formulas will be used.

$$\int_{p_{1-1}}^{p_1} \psi(r) r dr \approx \frac{1}{2} (p_1^2 - p_{1-1}^2) \psi(r_1) = V_1 \psi(r_1).$$

$$\int_{p_{1-1}}^{p_1} f_1(r) r dr \approx V_1 f_1(r_1)$$

With these approximations, the following matrices can be defined

$$G_1 = p_1 B_1 \Omega_1^{-1} \hat{A}_1, \quad N_1 \times N_{1+1}$$

$$H_1 = p_{1-1} \hat{B}_{1-1} \Omega_{1-1}^{-1} A_{1-1}, \quad N_1 \times N_{1-1}$$

$$E_1 = p_1 B_1 \Omega_1^{-1} A_1 + p_{1-1} \hat{B}_{1-1} \Omega_{1-1}^{-1} \hat{A}_{1-1} + V_1 \{E_1\}_1$$

for $i = 1, 2, \dots, I$ with $H_I = 0$, $G_I = 0$, and

$$\begin{aligned} E_1 &= p_1 D_1 \left[\gamma D_1 + \frac{1}{2} C_{EK}^R \delta_1^{-1} \right]^{-1} C_{EK}^R W_1 \\ &+ p_{1-1} \hat{B}_{1-1} \Omega_{1-1}^{-1} \hat{A}_{1-1} + \{E_1\}_1 \end{aligned} \quad (68)$$

where

$$\delta_1 = p_1 - p_{1-1}$$

and

$$W_1 = \begin{bmatrix} W_K \\ W_E \end{bmatrix}$$

At a regular interface, $N_i = N_{i+1}$, and $A_i = \hat{A}_i = B_i = \hat{B}_i = I$, thus, $H_{i+1} = G_i$. However, in general, $H_{i+1} \neq G_i$, therefore the matrices are not symmetric.

With the above matrices the differential system has been approximated by the following algebraic system

$$\begin{bmatrix} E_1 & -G_1 & 0 & 0 \\ -H_2 & E_2 & -G_2 & 0 \\ 0 & -H_3 & & \\ & & & -G_{l-1} \\ 0 & & -H_l & E_l \end{bmatrix} \Phi = f, \quad (69)$$

where $\Phi = [\Phi_1, \Phi_2, \dots, \Phi_l]$ and $\Phi_i = \Phi(r_i)$.

In the multigroup case, there are G matrices of the above form which will be denoted by P_g . Letting

$$ES = \text{diag}(V, ES)_{1 \times 1}^l$$

and

$$FS = \text{diag}(V, FS)_{1 \times 1}^l$$

for $1 \leq g \leq G$ and defining $\Phi_g = [\Phi_{g1}, \Phi_{g2}, \dots, \Phi_{gl}]$, the discrete approximation to the original differential equations system takes the form

$$P_g \Phi_g = \sum_{g'=1}^{G-1} ES \Phi_{g'} + \lambda \sum_{g'=1}^G FS \Phi_{g'}, \quad 1 \leq g \leq G. \quad (70)$$

Since $P_g^{-1} \geq 0$ and the matrices ES and FS are nonnegative, this system is solved for the dominant eigenvalue λ and eigenvector by the power technique. Thus, given any guess $\Phi^{(0)} > 0$ and $\lambda^{(0)}$ for the dominant eigenvector and eigenvalue, the successive approximations are generated by the following scheme.

$$P_g \Phi_g^{(n+1)} = \sum_{g'=1}^{G-1} ES \Phi_{g'}^{(n+1)} + \lambda^{(n)} \sum_{g'=1}^G FS \Phi_{g'}^{(n)} \quad (71)$$

Note that the desired k -effective is defined by the relation $k = 1/\lambda$.

and

$$\lambda^{(n)} = \lambda^{(n-1)} \frac{(\varphi^{(n)}, \varphi^{(n-1)})}{(\varphi^{(n)}, \varphi^{(n)})} \quad (72)$$

where

$$(\varphi, \varphi) = \sum_{g=1}^G \sum_{i=1}^I \sum_{l=1}^{N_i} \varphi_{lig} \varphi_{lig}$$

The generation of $\varphi^{(n+1)}$ thus involves the solution of the system

$$P_g \varphi_g = f_g \quad (73)$$

for $g = 1, 2, \dots, G$. Since each matrix P_g is block tridiagonal, each system can be solved directly by factoring the matrix P_g using a variant of Choleaski's method. For simplicity, the group index is dropped. Then $P = LU$, where L and U have the forms

$$\left. \begin{aligned} L &= \begin{bmatrix} U_1 & 0 & 0 \\ -H_2 & U_2 & 0 \\ 0 & -H_I & U_I \end{bmatrix} \\ U &= \begin{bmatrix} I & -V_1 & 0 & \dots & 0 \\ 0 & I & -V_2 & \dots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & \dots & -V_{I-1} & \dots & I \end{bmatrix} \end{aligned} \right\} \quad (74)$$

This factorization leads to the following recursive relations for the matrices U_i and V_i :

$$\left. \begin{aligned} U_1 &= E_1, \quad U_1 V_1 = G_1 \\ H_i V_{i-1} + U_i &= E_i, \quad U_i V_i = G_i, \quad 2 \leq i \leq I \quad (G_I = 0). \end{aligned} \right\} \quad (75)$$

With this factorization, the single system $P\varphi = f$ is equivalent to the pair of equations

$$L\varphi = f$$

and

$$U\varphi = \varphi$$

Hence,

$$\left. \begin{aligned} \omega_1 &= U_1^{-1} f_1; \\ \omega_i &= U_i^{-1} [f_i + H_i \omega_{i-1}], \quad 2 \leq i \leq I; \\ \phi_I &= \omega_I; \\ \phi_j &= \omega_j + V_j \phi_{j+1}, \quad I-1 \geq j \geq 1. \end{aligned} \right\} \quad (76)$$

The method requires the creation and storage of the matrices $\{U_i^{-1}\}_{i=1}^I$. However, these matrices can replace the matrices E_i , which are not needed in the actual solution.

5. Output Edits

Presently the printed output of the synthesis module is almost identical to the output of the two-dimensional diffusion-theory module, which is discussed below. Of interest here is the output that varies from the two-dimensional diffusion output in form and/or content.

Each page of the output is numbered and titled with a user-supplied heading.

The edits that may appear from this module may be divided into four sections: input, iterations, mixing functions, and output.

a. Input. The input section is divided into several parts. In the first part the code prints out the following items, which were user-input:

- (1) Maximum number of outer iterations (NMAX).
- (2) k-effective difference convergence criterion, ϵ_k .
- (3) Normalized-flux difference convergence criterion, ϵ_f .

$$\left(\sum_{gin} |\phi_{gin}^{t+1} - \phi_{gin}^t| / GIN \sum_{gin} |\phi_{gin}^{(t+1)}| \right) \leq \epsilon_f,$$

where G is the number of energy groups, l is the number of X-direction intervals, and N is the maximum number of real trial functions in any synthesis region.

(4) Lambda-limit difference convergence criterion, ϵ_λ , where

$$\bar{\lambda} = \max_{gin} w_{gin}, \quad \underline{\lambda} = \min_{gin} w_{gin} \quad \text{and} \quad w_{gin} = |\phi_{gin}^t / \phi_{gin}^{(t-1)}|.$$

- (5) Power-normalization factor for a burnup calculation, P_0 , in watts (set to one if input is zero or blank)
- (6) Size of the POINTER core container allocated in double words, for both main and bulk core
- (7) Interface condition to be used at each internal synthesis region boundary.
- (8) Indication of which trial functions will be used as adjoints, i.e., either SYN2D will use the real trial functions supplied, or the user will also supply adjoint trial functions

The second part states the geometry type (RZ, ZR, or XY) and describes the mesh structure, region and composition assignments, and buckling, region half-heights, and extrapolation distances

The third part displays the group-dependent macroscopic cross section for each composition defined. The diffusion coefficient shown was calculated from the transport cross section [$D = 1/(3\Sigma_{tr})$].

The fourth part describes the type of boundary condition applied by space point and energy group.

Then the geometry type (XY, RZ, or ZR) and the internal synthesis boundary points, along with the number of refined regions and the time spent in the execution of the synthesis input processor, is printed. This is followed by an approximation to the condition number of $D_{gk}(r)$. This approximation is computed by taking the column norms of $[D_{gk}(r)]$ and of $[D_{gk}(r)]^{-1}$. The product of these two norms is computed for all r , and the largest is printed out for each group, indicating which synthesis region is occurred in. Then the time required to compute all the calculated matrices is printed out.

b. Iteration History. Ten columns of monitoring information are printed out as the code iterates. This enables the user to study the convergence of the iterates and to observe where any problems might have occurred. The information printed out is in order as follows for each iteration:

- (1) The outer iteration number.
- (2) The number of inner iterations. (This is always zero, since no upscattering is handled.)
- (3) The last approximation to k -effective, i.e., the value obtained by the previous outer iteration.
- (4) The difference between (3) and the present k -effective computed in this iteration (see a(2)).

- (5) Lambda up $\bar{\lambda}$ (see a(4)).
- (6) Lambda down $\underline{\lambda}$ (see a(4)).
- (7) Lambda difference (see a(4)).
- (8) The sum of the absolute values of the new mixing functions, minus the old mixing functions.
- (9) The sum of the absolute values of the old mixing functions.
- (10) Normed quotient of (8) and (9) (see a(3)).

The iteration process stops when we exceed the number of outer iterations or when the number given by (4) is less than ϵ_k and the number given by (7) is less than ϵ_λ and the number given by (10) is less than ϵ_f . The time for the iteration section is then printed out.

c. Mixing Functions The calculated mixing functions for each group and the user-input real trial functions for each group and synthesis region are printed out. The time required to do this and calculate the reconstructed 2-D fluxes is also printed out.

d. Output Five basic categories of output inventories appear: flux, flux integrals, fission integrals, power calculations, and balance calculations.

The following output section is the same as for the two-dimensional diffusion-theory module; however, synthesis cannot handle R θ geometry, and external source calculation or an adjoint problem. Items not applicable are indicated by an asterisk.

All inventories are based on weighted integrals of the flux as a function of three spatial variables and one energy variable, with the integrals extending over the dimensions of the reactor defined in a given problem.

The following shapes were assumed for the flux in each of the four geometries:

- (1) RZ or ZR: $(r, z, \theta) = \phi(r, z)$
- (2) XY finite: $(x, y, z) = \phi(x, y) \cos \frac{\pi z}{2H_R}$
- XY infinite: $(x, y, z) = \phi(x, y)$

(77)
(Contd.)

$$\left. \begin{array}{ll} (3) \text{ R6 finite} & \phi(r,z,\theta) = \phi(r,\theta) \cos \frac{\pi z}{2H_R} \\ \text{R6 infinite} & \phi(r,z,\theta) = \phi(r,\theta) \end{array} \right\} \quad \begin{array}{l} \text{(Contd.)} \\ (77) \end{array}$$

where H_R is the region half-height plus the extrapolation distance

Consider any macroscopic cross section $\sigma^R(R)$, where R denotes a particular region in the reactor. Using XY geometry as an example, a typical inventory might involve the numerical approximation to the following integral

$$\begin{aligned} I_{R,g} &= \int_{x,y \in R} \int_{-(H_L)_R}^{(H_L)_R} \sigma^R(R) \phi_g(x,y) \cos \frac{\pi z}{2H_R} dz dx dy \\ &= \int_{x,y \in R} \sigma^R(R) \phi_g(x,y) \frac{4H_R}{\pi} \sin \frac{\pi(H_L)_R}{2H_R} dx dy \\ &\approx W_R \sigma^R(R) \sum_{x,y \in R} \phi_g(x,y) V_{x,y} \end{aligned} \quad (78)$$

where

$$W_R = \frac{4H_R}{\pi} \sin \frac{\pi(H_L)_R}{2H_R}$$

$V_{x,y}$ is the volume per unit height of a cell,

and

$(H_L)_R$ is the physical half-height of region R .

For each geometry type, the following table gives the physical volumes and integration weighting factor by region:

Geometry	$\sum V_i$	W_i
RZ 2D	$\sum_{i \in R} V_i$	1
XY finite	$\sum_{i \in R} V_{x,y}$	$\frac{4H_R}{\pi} \sin \frac{\pi(H_L)_R}{2H_R}$
XY infinite	$\sum_{i \in R} V_i$	1
RZ finite	$\sum_{i \in R} V_i$	$\frac{4H_R}{\pi} \sin \frac{\pi(H_L)_R}{2H_R}$
RZ infinite	$\sum_{i \in R} V_i$	1

The area associated with each side of the cell and values for each geometry are given below.

Geometry	A_L	A_R	A_T	A_B	Volume
XY	Δy_j	Δy_j	Δx_i	Δx_i	$\Delta x \Delta y$
R θ	$R_{i-1} \Delta \theta_j$	$R_i \Delta \theta_j$	$\Delta R_i \cos \frac{\Delta \theta_j}{4}$	$\Delta R_i \cos \frac{\Delta \theta_j}{4}$	$\frac{\Delta \theta_j}{2} (R_{i+1}^2 - R_i^2)$
RZ	$2\pi R_{i-1} \Delta Z_j$	$2\pi R_i \Delta Z_j$	$\pi(R_i^2 - R_{i-1}^2)$	$\pi(R_i^2 - R_{i-1}^2)$	$\pi(R_{i+1}^2 - R_i^2) \Delta Z_j$

For a homogeneous calculation, the fluxes are normalized to one fission in the reactor. The normalization factor is calculated the following way:

$$\begin{aligned} \phi_{r,g} &= \sum_{i,j \in R} \phi_{i,j,g}^{(\text{computed})} V_{ij} \\ \text{and} \\ N &= \sum_{g=1}^G \sum_{r=1}^R W_R(\sigma_f)_{R,g} \phi_{r,g} \end{aligned} \quad (79)$$

where N is the normalization factor.

For an inhomogeneous calculation, no normalization is involved.

We can now display the calculations made in each of the five categories.

(1) Neutron Flux. $\phi_{i,j,g} = \phi_{i,j,g}^{(\text{computed})} / N.$

(2) Flux and Fission Integrals

a. Real or adjoint* regional flux integrals by group

$$\phi_{R,g} = W_R \sum_{i,j \in R} \phi_{i,j,g} V_{ij}$$

b. Real power-normalized regional flux averages by group, where P_0 (in watts) is an input parameter

$$\bar{\phi}_{R,g} = \frac{\phi_{R,g}}{V_R} (5.1 \times 10^{10} \times P_0)$$

c Removal by region and group

$$R_{R,G} = \left(\sigma_G^{\text{Rem}} + D_G^c B_R^2 + \frac{\alpha}{v_G} \right) \phi_{R,G}$$

$$R_R = \sum_G R_{R,G} \quad R_G = \sum_R R_{R,G}$$

d Absorption by region and by group

$$A_R = \sum_G (\Sigma_a)_{R,G} \phi_{R,G}$$

$$A_G = \sum_R (\Sigma_a)_{R,G} \phi_{R,G}$$

e Scattering by region and group

$$SS_{R,G} = \sum_{h=1}^G \sigma_{h \rightarrow g} \phi_{R,h}$$

$$SS_R = \sum_G SS_{R,G} \quad SS_G = \sum_R SS_{R,G}$$

f Fission source (real)

$$F_{R,G} = \chi_G \sum_{h=1}^G \sim \sigma_h^F \phi_{R,h} \text{ for a } \chi\text{-vector}$$

$$F_{R,G} = \sum_{h=1}^G \chi^{h \rightarrow G} \sim \sigma_h^F \phi_{R,h} \text{ for a } \chi\text{-matrix*}$$

Fission source (adjoint*)

$$F_{R,G} = \sim \sigma_G^F \sum_{h=1}^G \chi_h \phi_{R,h} \text{ for a } \chi\text{-vector}$$

$$F_{R,G} = \sim \sigma_G^F \sum_{h=1}^G \chi^{h \rightarrow G} \phi_{R,h} \text{ for a } \chi\text{-matrix*}$$

$$F_R = \sum_G F_{R,G} \quad F_G = \sum_R F_{R,G}$$

For an external source problem*

$$F(R,G) = \mu F(R,G)$$

* Leakage

$$L_{R,G} = W_R \sum_{ij \in R} L_{i,j,G}$$

$$L_R = \sum_G L_{R,G} \quad L_G = \sum_R L_{R,G}$$

The net leakage from cell (i,j) is given by

$$L_{ijg} = J_L A_L + J_R A_R + J_T A_T + J_B A_B$$

where J is the current, which may also be printed out by region and group. A is the area, and the subscripts L, R, T, and B indicate the left, right, top, and bottom.

For XY geometry:

Internal cell (i,j)

$$\left. \begin{aligned} J_R &= \frac{D_{i,j,g} D_{i+1,j,g} (\psi_{i+1,j,g} - \psi_{i,j,g})}{\frac{1}{2} (\Delta x_i D_{i+1,j,g} + \Delta x_{i+1} D_{i,j,g})} \\ J_L &= \frac{D_{i,j,g} D_{i-1,j,g} (\psi_{i,j,g} - \psi_{i-1,j,g})}{\frac{1}{2} (\Delta x_i D_{i-1,j,g} + \Delta x_{i-1} D_{i,j,g})} \\ J_T &= \frac{D_{i,j,g} D_{i,j+1,g} (\psi_{i,j+1,g} - \psi_{i,j,g})}{\frac{1}{2} (\Delta y_j D_{i,j+1,g} + \Delta y_{j+1} D_{i,j,g})} \\ J_B &= \frac{D_{i,j,g} D_{i,j-1,g} (\psi_{i,j,g} - \psi_{i,j-1,g})}{\frac{1}{2} (\Delta y_j D_{i,j-1,g} + \Delta y_{j+1} D_{i,j,g})} \end{aligned} \right\} \quad (90)$$

External cell (boundary condition $A\phi + B\psi = C$)

$$\left. \begin{aligned} J_R &= -D_{1,j,g} (C - B\phi_{1,j,g}) / (A + \frac{1}{2}\Delta x_j B) \\ J_L &= D_{1,j,g} (B\phi_{1,j,g} - C) / (A + \frac{1}{2}\Delta x_j B) \\ J_T &= -D_{1,j,g} (C - B\phi_{1,j,g}) / (A + \frac{1}{2}\Delta y_j B) \\ J_B &= D_{1,j,g} (B\phi_{1,j,g} - C) / (A + \frac{1}{2}\Delta y_j B) \end{aligned} \right\} \quad (81)$$

Here $D_{1,j,g}$ is the diffusion coefficient by point and group, and the areas for each geometry are defined previously

For RZ or ZR geometry

The form of the equations is identical to those written for XY geometry (Eqs 80 and 81).

For Rθ geometry*

Internal cell (1,j)

$$\begin{aligned} J_R &= -\frac{D_{1,j,g} D_{1+1,j,g} (\phi_{1+1,j,g} - \phi_{1,j,g})}{\frac{1}{2}(\Delta r_1 D_{1+1,j,g} + \Delta r_{1+1} D_{1,j,g})} \\ J_L &= \frac{D_{1,j,g} D_{1-1,j,g} (\phi_{1,j,g} - \phi_{1-1,j,g})}{\frac{1}{2}(\Delta r_1 D_{1-1,j,g} + \Delta r_{1-1} D_{1,j,g})} \\ J_T &= -\frac{D_{1,j,g} D_{1,j+1,g} \cos \frac{\Delta\theta_{j+1} - \Delta\theta_j}{4} (\phi_{1,j+1,g} - \phi_{1,j,g})}{\frac{1}{2}(\delta_{1,j} D_{1,j+1,g} + \delta_{1,j+1} D_{1,j,g})} \\ \delta_{1,j} &= \frac{\phi_U}{1 + \omega_U}, \quad \delta_{1,j+1} = \frac{\omega_U \phi_0}{1 + \omega_U} \\ J_B &= \frac{D_{1,j,g} D_{1,j-1,g} \cos \frac{\Delta\theta_j - \Delta\theta_{j-1}}{4} (\phi_{1,j,g} - \phi_{1,j-1,g})}{\frac{1}{2}(\delta_{1,j} D_{1,j-1,g} + \delta_{1,j-1} D_{1,j,g})} \end{aligned}$$

External cell (boundary condition, $A\phi + B\psi = C$)

$$\begin{aligned} J_R &= -D_{1,j,g} (C - B\phi_{1,j,g}) / (A + \frac{1}{2}\Delta x_j B) \\ J_L &= D_{1,j,g} (B\phi_{1,j,g} - C) / (A + \frac{1}{2}\Delta x_j B) \end{aligned}$$

$$J_T = -D_{1,j,g}(C - B\phi_{1,j,g}) / \left[A + B(r_{1+1} + r_1) \sin \frac{\Delta\theta_j}{4} \right];$$

$$J_B = D_{1,j,g}(B\phi_{1,j,g} - C) / \left[A + B(r_{1+1} + r_1) \sin \frac{\Delta\theta_j}{4} \right];$$

h Inhomogeneous case-external source*

$$ES_{r,g} = W_R \sum_{1,j \in R} E_{1,j,g} V_{1,j}$$

where $E_{1,j,g}$ is the external source

(3) Power Calculations

a Power density by interval

$$P_{1,j} = \sum_{g=1}^G \sigma_{1,j,g}^F \phi_{1,j,g}$$

b Maximum $P_{1,j}$ and minimum $P_{1,j}$ [$P_{1,j} > 0$]

c Power by region

$$P_R = \sum_{g=1}^G \sigma_{R,g}^F R_{R,g}$$

d Average power by region

$$\bar{P}_R = P_R / V_R$$

e Total power

$$P = \sum_R P_R$$

(4) Balance Calculations

$$B_{R,G} = -L_{R,G} - R_{R,G} + SS_{R,G} + \frac{1}{k_{eff}} FS_{R,G}$$

For an inhomogeneous problem*

$$B_{R,G} = -L_{R,G} - R_{R,G} + SS_{R,G} + FS_{R,G} + ES_{R,G}$$

Also displayed are balances by region, balances by group and total balance

$$B_R = \sum_G B_{R,G} = B_G = \sum_R B_{R,G}$$

$$B = \sum_{R,G} B_{R,G}$$

6 Implementation of Particular Interface Conditions

The following choice for the current interface trial functions appearing in Eqs. 25 and 26 has been suggested by V. Luro. At the interface R_k between the k th and $(k+1)$ st synthesis region, set

$$A_{gm}^k(z) = D_g^k(R_k, z) H_{gm}^{*k}(z), \quad (82)$$

and

$$B_{gn}^k(z) = D_g^k(R_k, z) H_{gn}^k(z), \quad (83)$$

where $D_g^k(R_k, z)$ denotes the diffusion constant for the g th group evaluated at the left side of the interface R_k . With this choice for the current interface trial functions, the interface matrices defined in Eqs. 35-38 take the following form

$$A_{gk}^{mn} = \int_0^h D_g^k(R_k, z) H_{gm}^{*k}(z) H_{gn}^k(z) dz, \quad (84)$$

$$\bar{A}_{g(k+1)}^{mn} = \int_0^h D_g^k(R_k, z) H_{gm}^{*k}(z) H_{gn}^{k+1}(z) dz, \quad (85)$$

$$B_{gk}^{mn} = \int_0^h D_g^k(R_k, z) H_{gm}^{*k}(z) H_{gn}^k(z) dz, \quad (86)$$

and

$$\bar{B}_{g(k+1)}^{mn} = \int_0^h D_g^k(R_k, z) H_{gm}^{*k+1}(z) H_{gn}^k(z) dz, \quad (87)$$

Note that in this case the matrices $A_{gk}^k = (A_{gk}^{mn})$ and $B_{gk}^k = (B_{gk}^{mn})$ are equal and also equal to the matrix $D_g^k(R_k)$ defined in Eq. 28. These matrices are then used in the interface conditions defined by Eqs. 60-62.

As noted earlier in Section II.B.3, the formalism of this program was used to implement a synthesis procedure based on the method of weighted residuals. As shown, this method differs from the variational approach in that the number of trial functions must be the same in each synthesis region and the general Busby interface conditions as defined by Eqs. 60-62 are replaced by interface conditions of the form

$$[\hat{V}_E^k]^{-1} \hat{V}_E^k(R_k) = [W_E^k]^{-1} \hat{V}_E^{k+1}(R_k) \quad (88)$$

$$[\hat{K}_E^k] \frac{d}{dr} \hat{V}_E^k(r) \Big|_{r=R_k} = [\hat{L}_E^{k+1}] \frac{d}{dr} \hat{V}_E^{k+1}(r) \Big|_{r=R_k} \quad (89)$$

The condition on the continuity of the flux is of the same form as in Eq. 60. However, the condition on the continuity of the current differs somewhat from the general form as given in Eqs. 61-62. These conditions can be written in the form

$$\frac{d\hat{V}_E^k(r)}{dr} \Big|_{r=R_k} - [D_E^k(R_k)]^{-1} [\hat{B}_E^k]_E^k = 0 \quad (90)$$

$$\frac{d\hat{V}_E^{k+1}(r)}{dr} \Big|_{r=R_k} + [D_E^{k+1}(R_k)]^{-1} [\hat{B}_E^{k+1}]_E^{k+1} = 0 \quad (91)$$

Since the conditions expressed by Eqs. 90 and 91 are more general than that of Eq. 89, we can choose the matrices $[\hat{B}_E^k]$ and $[\hat{B}_E^{k+1}]$ in order to reduce Eqs. 90 and 91 to Eq. 89. To this end, apply condition 89 in Eqs. 90 and 91; then the following relation or constraint is established:

$$[\hat{K}_E^k][D_E^k(R_k)]^{-1}[\hat{B}_E^k] = [\hat{L}_E^{k+1}][D_E^{k+1}(R_k)]^{-1}[\hat{B}_E^{k+1}] \quad (92)$$

The following choice was made for simplicity in programming:

$$[\hat{B}_E^k] = [D_E^k(R_k)][\hat{K}_E^k]^{-1} \quad (93)$$

$$[\hat{B}_E^{k+1}] = [D_E^{k+1}(R_k)][\hat{L}_E^{k+1}]^{-1} \quad (94)$$

7. Integration Procedures and the Formation of Partial Integrals

As seen in Section II.B.3, an essential part of the synthesis approach involves the approximation of the integrals appearing in Eqs. 35-38, with Eqs. 35-38 redefined as in Section 6 above.

The program is given the following

a. A subdivision

$$0 = h_0 < h_1 < \dots < h_n = n$$

of the interval $[0, n]$.

b. A single value associated with $H_{gm}^{k*}(z)$ in each interval $[h_{s-1}, h_s]$ and a single value associated with $H_{gn}^k(z)$ in the same interval.

c. The value associated with each cross section in each interval $[h_{s-1}, h_s]$. The cross sections are assumed constant in each interval.

Since in principle the trial functions $H_{gm}^{k*}(z)$ and $H_{gn}^k(z)$ do not correspond in any way to the particular region of the reactor over which they are being integrated, the most that can be assumed is that the tabular values represent parameters associated with an approximation to a continuous function. It is assumed that the tabular values for the trial functions are generated by means of the two-dimensional diffusion-theory code DARC2D which is a member of the ARC System. In this case the tabulated values of the trial functions can be associated with the evaluation at the midpoint z_s of the subinterval $[h_{s-1}, h_s]$ of a piecewise linear and continuous function on the interval $[0, n]$.

However, in the diffusion-theory model, the continuous piecewise linear functions have joints at the midpoints z_s and at the subinterval boundaries h_s . The position of the joint at the interface is constrained through the condition of continuity of current. This constraint cannot be used in this program since the trial functions are used in regions that are not related to the regions in which these functions were determined. For this reason the class of piecewise linear functions associated with the tabular values is taken to have joints only at the midpoints z_s of the subintervals $[h_{s-1}, h_s]$.

Since the cross sections are assumed constant in each subinterval, all the integrals appearing in Eqs. 29-34 are sums of integrals of either of the following two types:

$$\int_{h_{s-1}}^{h_s} H^*(z) H(z) dz \quad (95)$$

and

$$\int_{h_{s-1}}^{h_s} \frac{dH^*(z)}{dz} \frac{dH(z)}{dz} dz \quad (96)$$

Here we have dropped the indices k , n , m , and g , since they are irrelevant at this point.

By assumption, $H(z)$ and $H^*(z)$ are piecewise linear with joints at z_g thus each has the following representation in the subinterval $[h_{g-1}, h_g]$:

$$I(z) = \begin{cases} \frac{(z - z_{g-1}) f(z_g) - (z_g - z) f(z_{g-1})}{z_g - z_{g-1}} & \text{for } h_{g-1} \leq z \leq z_g \\ \frac{(z - z_g) f(z_{g+1}) + (z_{g+1} - z) f(z_g)}{z_{g+1} - z_g} & \text{for } z_g \leq z \leq h_g \end{cases} \quad (97)$$

where $I(z)$ represents either $H(z)$ or $H^*(z)$.

This representation for $H(z)$ and $H^*(z)$ is used in the integral 95 and the resulting quadratic (or cubic if the direction is curvilinear) polynomial is integrated exactly over the subinterval $[h_{g-1}, h_g]$. In the same manner the derivative of the representation 97 is used to approximate the integral 96.

The quadrature formulas resulting from these approximations are moderately accurate in the case of integrals of type 95. These formulas are somewhat less accurate than those used in the inventory modules for diffusion-theory fluxes, since continuity of current has not been accounted for in this case. However, thus far, numerical experience on model problems has indicated that the accuracy of the quadrature formula for 95 is commensurate with the information content of the tabulated values for the trial functions in the following sense. If the trial functions are generated by means of diffusion theory, for the case of model problems, then discrepancies in the flux produced by synthesis versus the flux produced by diffusion theory do not arise from the quadrature formula for 95. Indeed, in the model problems, the discrepancies arose from the quadrature formula for 96. Higher-order quadrature formulas were tried on the model problem in an effort to remove the discrepancies. A quadrature formula for 96 was used which was based on the assumption that $H(z)$ and $H^*(z)$ were piecewise quadratics. (In the model problem there were no region boundaries.) The gain in accuracy for this case was only a half place in k -effective.

Having discussed the quadrature schemes used for approximating Eq. 96, we now describe the procedure by which the cross-section matrices, given by Eqs 28-38, are generated by this program.

Remembering that the reactor composition structure is a function of R and Z but not θ allows the reactor to be envisioned as a flat slab. The mesh structure imposed upon the reactor divides it into a

number of mesh cells c_{ij} , $1 \leq i \leq I$ and $1 \leq j \leq J$, where I is the number of intervals in the R or synthesis direction with r_i , $0 \leq i \leq I$, as the interval endpoints and J is the number of intervals in the Z or transverse direction with z_j , $0 \leq j \leq J$, as the interval endpoints. Each mesh cell is contained in some reactor region R which has a unique composition assigned to it. These reactor regions are actually the union of several contiguous rectangles and may cross synthesis boundaries, however, only one composition is assigned to the entire reactor region. The synthesis region boundaries fall on interval boundaries z_k . Consider a synthesis region k , and let $R_{p,j}$ be the region in which the j mesh cell lies. Define a cut ℓ as the set of mesh cells c_{ij} , $1 \leq j \leq J$, associated with interval i . Starting at the first cut p in synthesis region k , compare $R_{p,j}$ and $R_{p+1,j}$ for all j . If $R_{p,j} = R_{p+1,j}$ for all values of j , then cuts p and $p+1$ are said to lie in the same refined region. This comparison is repeated for cuts $p+1$ and $p+2$ and continued until cuts $p+\ell$ and $p+\ell+1$ are compared with cut $p+\ell+1$ the last cut in synthesis region k . In this manner, the synthesis region k is divided into N refined regions. Each refined region $\bar{r}$ contains a set of contiguous cuts with the property that for any two cuts p and q in $\bar{r}$, $R_{p,j} = R_{q,j}$ for $1 \leq j \leq J$; i.e., all cuts in a refined region are identical. Now for each refined region $\bar{r}$, let $\{z_{r,j}\}$ be the set of mesh-point boundaries dividing the j and $(j+1)$ st intervals for which $R_{p,j} \neq R_{p,j+1}$ with cut p in refined region $\bar{r}$. Then

$$\bigcup_r \{z_{r,j}\}$$

where r is a refined region in synthesis region k , yields an ordered set of points y_ℓ , $1 \leq \ell \leq L_k - 1$. To this set is added $y_0 = z_0$ and $y_{L_k} = z_J$. These points define the limits of integration for the partial integrals to be defined below. Next define the interval $[y_{\ell-1}, y_\ell]$ as the ℓ th refined interval in synthesis region k . Note that the $(k+1)$ st synthesis region will, in general, have a different region to mesh assignment and hence will not have the same number of refined regions or the same refined interval structure as synthesis region k .

Defined below are the five types of partial integrals calculated by SYNZD. Each integral is evaluated as the sum of several integrals which are approximated in the manner described previously; i.e.,

$$\int_{y_{\ell-1}}^{y_\ell} H_{gm}^{*k}(z) H_{gn}^k(z) dz = \sum_{s=\underline{s}}^{\bar{s}} \int_{z_{s-1}}^{z_s} H_{gm}^{*k}(z) H_{gn}^k(z) dz$$

with $z_{\underline{s}-1} = y_{\ell-1}$ and $z_{\bar{s}} = y_\ell$. The partial integrals $j_{g,g}^{mn}$, $j_{g,g}^{mn}$, Q_g^{mn} , p_g^{mn} and $\bar{p}_g^{mn}$ are calculated as follows:

$$I_{g'g}^{mn}(\ell, k) = \int_{y_{\ell-1}}^{y_{\ell}} H_{gm}^{*k}(z) H_{g'n}^k(z) dz \quad \begin{matrix} 1 \leq m \leq N_{gk}, \\ 1 \leq n \leq N_{g'k}, \end{matrix} \quad (98)$$

$$J_g^{mn}(\ell, k) = \int_{y_{\ell-1}}^{y_{\ell}} \frac{dH_{gn}^{*k}(z)}{dz} \frac{dH_{gn}^k(z)}{dz} dz, \quad 1 \leq m, n \leq N_{gk}, \quad (99)$$

$$\hat{P}_g^{mn}(\ell, k+1) = \int_{y_{\ell-1}}^{y_{\ell}} H_{gm}^{*k}(z) H_{gn}^{k+1}(z) dz, \quad \begin{matrix} 1 \leq m \leq N_{gk}, \\ 1 \leq n \leq N_{g, k+1}, \end{matrix} \quad (100)$$

$$P_g^{mn}(\ell, k) = \int_{y_{\ell-1}}^{y_{\ell}} H_{gm}^{*k+1}(z) H_{gn}^k(z) dz, \quad \begin{matrix} 1 \leq m \leq N_{g, k+1}, \\ 1 \leq n \leq N_{gk}, \end{matrix} \quad (101)$$

$$Q_g^{mn}(\ell, k) = \int_{y_{\ell-1}}^{y_{\ell}} H_{gm}^{*k}(z) H_{gn}^{k+1}(z) dz, \quad \begin{matrix} 1 \leq m \leq N_{gk}, \\ 1 \leq n \leq N_{g, k+1}, \end{matrix} \quad (102)$$

with ℓ a refined interval in synthesis region k , and $\hat{\ell}$ a refined interval in synthesis region $k+1$.

Now the integrals defined in Eqs. 28-34 can be expressed as weighted sums of the above partial integrals expressed in the following form:

$$D_{gk}^{mn}(\bar{r}) = \sum_{\ell} D_g(\bar{r}, z_{\ell}) I_{gg}^{mn}(\ell, k), \quad (103)$$

$$L_{gk}^{mn}(\bar{r}) = \sum_{\ell} D_g(\bar{r}, z_{\ell}) J_g^{mn}(\ell, k), \quad (104)$$

$$\Sigma_{gk}^{mn}(\bar{r}) = \sum_{\ell} \Sigma_{rg}(\bar{r}, z_{\ell}) I_{gg}^{mn}(\ell, k), \quad (105)$$

$$\Sigma_{g'g, k}^{mn}(\bar{r}) = \sum_{\ell} \Sigma_{g'g}(\bar{r}, z_{\ell}) I_{g'g}^{mn}(\ell, k), \quad (106)$$

$$(\chi_g v_g, \Sigma_{lg})_k^{mn}(\bar{r}) = \sum_{\ell} (\chi_g v_g, \Sigma_{lg})(\bar{r}, z_{\ell}) I_{gg}^{mn}(\ell, k), \quad (107)$$

and

$$W_{gk}^{mn} = \sum_{\ell} I_{gg}^{mn}(\ell, k), \quad k = 1 \text{ and } K, \quad (108)$$

where $z_{\ell} = 0.5 (y_{\ell} - y_{\ell-1})$, ℓ a refined interval in synthesis region k , and $\bar{r}$ a refined region in synthesis region k

The integrals defined for the Luo interface in Section 6 are defined as follows

$$A_{gk}^{mn} = B_{gk}^{mn} \sum_{\ell} D_g(R_k, z_{\ell}) I_{gg}^{mn}(\ell, k), \quad (109)$$

$$\bar{A}_{g(k+1)}^{mn} = \sum_{\ell} D_g(R_k, z_{\ell}) Q_g^{mn}(\ell, k), \quad (110)$$

and

$$\bar{B}_{g(k+1)}^{mn} = \sum_{\ell} D_g(R_k, z_{\ell}) P_g^{mn}(\ell, k), \quad (111)$$

with ℓ , z_{ℓ} , and $\bar{r}$ as previously defined.

The integrals defined for the Stacey interface in Eqs. 55-58 are defined below, with $\hat{\ell}$ a refined interval in synthesis region $k+1$ and $z_{\hat{\ell}} = 0.5 (y_{\hat{\ell}} - y_{\hat{\ell}-1})$.

$$\hat{V}_{gk}^{mn} = \sum_{\ell} [I_{gg}^{mn}(\ell, k) + P_g^{mn}(\ell, k)], \quad (112)$$

$$\hat{W}_{g(k+1)}^{mn} = \sum_{\hat{\ell}} [I_{gg}^{mn}(\hat{\ell}, k+1) + \hat{P}_g^{mn}(\hat{\ell}, k+1)], \quad (113)$$

$$\hat{K}_{gk}^{mn} = \sum_{\ell} D_g(R_k, z_{\ell}) [I_{gg}^{mn}(\ell, k) + P_g^{mn}(\ell, k)], \quad (114)$$

$$\hat{L}_{g(k+1)}^{mn} = \sum_{\hat{\ell}} D_g(R_k, z_{\hat{\ell}}) [I_{gg}^{mn}(\hat{\ell}, k+1) + \hat{P}_g^{mn}(\hat{\ell}, k+1)], \quad (115)$$

Defining partial integrals and then using weighted sums to calculate the required integrals has several advantages. First, less computation is required, since many of the integrals differ only in the cross sections used as weighting coefficients, i.e., $D_{kk}^{nn}(\bar{r})$ and $\Gamma_{kk}^{nn}(\bar{r})$ of Eqs. 103 and 105. Second, it is anticipated that the users of SYN2D will be running successive test cases using reactors that are identical in mesh structure, synthesis region definitions, and mesh-point-to-reactor-region assignments, but will differ in the compositions assigned to each reactor region. Generating partial integrals once and saving the results allows successive cases to be run without the necessity of regenerating the same partial integrals for each run and thus effects a savings in time.

Finally, note that the integrals defined by Eqs. 103-107 are defined for every refined region of the reactor. Any integral required by the finite-difference algorithm is computed over some cut p which lies in some refined region $\bar{r}$. Thus the set of integrals defined by Eqs. 103-107 contains the required integrals for all cuts of the reactor.

8. Other Geometries and Synthesis-region Configurations

Now, with only minor modifications of the discussion in Section 7 above, two additional cases can be considered:

a. The same cylindrical reactor but with synthesis regions defined as axial slabs, starting at the reactor bottom, or

b. A flat slab reactor bounded by the planes $0 \leq x \leq a$, $0 \leq y \leq b$, which can be of either bounded or unbounded length in the z direction. The k th synthesis region is then a slab of the form $x_{k-1} \leq x \leq x_k$, $0 \leq y \leq b$, and all z , where x_0 and x_K equal 0 and a , respectively.

The variational functional to be used for Case a is

$$J[u_R^k(r,z), u_R^{k*}(r,z), \phi_R^k(z), \beta_R^k(z)] = \sum_{k=1}^K \left\langle 2\pi \int_{V_k} \sum_{g=1}^G \left\{ \phi_R^{k*} \cdot D_R \nabla u_R^k + u_R^{k*} \left[\Gamma_R u_R^k - \sum_{k'=1}^{G-1} \Gamma_{R,k'} u_R^{k'} - \lambda_{R,k} \sum_{g=1}^G (v \Sigma_f)_{R,k} u_R^k \right] \right\} r dr dz \right. \\ \left. + \sum_{k=1}^{K-1} \left\langle 2\pi \int_0^R \left\{ \sum_{g=1}^G \phi_R^{k+1} [u_R^{(k+1)}(r, z_k) - u_R^k(r, z_k)] + [u_R^{(k+1)*}(r, z_k) - u_R^{k*}(r, z_k)] \beta_R^k \right\} r dr \right\rangle \right. \quad (116)$$

(Contd.)

$$\begin{aligned}
& \sum_{k=1}^G \left[\sum_{k=1}^K \left\langle 2\pi R \int_{z_{k-1}}^{z_k} \left\{ \alpha_{KK}^R u_g^{k*}(R, z) u_g^k(R, z) \right. \right. \right. \\
& \quad \left. \left. + (1 - \epsilon) \left[u_g^{k*}(R, z) D_g \frac{\partial u_g^k}{\partial r} \right]_{r=R} + u_g^k(R, z) D_g \frac{\partial u_g^{k*}}{\partial r} \right]_{r=R} \right\} dz \right. \\
& \quad \left. + 2\pi \int_{z_{k-1}}^{z_k} \left\{ \frac{\partial u_g^{k*}}{\partial r} \right|_{r=0} - \frac{\partial u_g^k}{\partial r} \right|_{r=0} \right\} dz \right. \\
& \quad \left. + 2\pi \int_0^R \left\{ \alpha_{KK}^T u_g^{k*}(r, h) u_g^k(r, h) + (1 - \epsilon) \left[u_g^{k*}(r, h) D_g \frac{\partial u_g^k}{\partial z} \right]_{z=h} \right. \right. \\
& \quad \left. \left. + u_g^k(r, h) D_g \frac{\partial u_g^{k*}}{\partial z} \right|_{z=h} \right\} r dr + 2\pi \int_0^R \left\{ \alpha_{KK}^B u_g^{k*}(r, 0) u_g^k(r, 0) \right. \\
& \quad \left. + (1 - \epsilon) \left[u_g^{k*}(r, 0) D_g \frac{\partial u_g^k}{\partial z} \right]_{z=0} + u_g^k(r, 0) D_g \frac{\partial u_g^{k*}}{\partial z} \right|_{z=0} \right\} r dr \Bigg]
\end{aligned}$$

(Contd.)
(116)

where V_g is the volume between $z_{k-1} \leq z \leq z_k$, $0 \leq r \leq R$.

The K synthesis regions have as their boundaries z_k , where $0 \leq z_1 \leq \dots \leq z_{K-1} < h$; $u_g^{k*}(r, z), u_g^k(r, z)$ are independent-variable functions defined as previously in the k th synthesis region; $u_g^k(r), \beta_g^k(r)$ are functions of r only, defined at the surfaces $z = z_k$.

Now proceeding in the same manner as previously, i.e., using Green's theorem and varying $u_g^{k*}(r, z)$ and $\alpha_g^k(r)$ arbitrarily, we obtain the following necessary conditions for stationariness, where ϕ_g^k and j_g^k are written for the stationary values of u_g^k and β_g^k :

$$-\nabla \cdot (D_g \nabla \phi_g^k) + 2\pi r g \phi_g^k - \sum_{g=1}^{G-1} \epsilon_{g'g} \phi_{g'}^k - \lambda_{\lambda_g} \sum_{g'=1}^G \{ \nu \epsilon_{g'} \}_{g'} \phi_{g'}^k = 0,$$

$$k = 1, \dots, K;$$

(117)

$$\phi_g^{(k+1)}(r, z_k) = \phi_g^k(r, z_k), \quad k = 1, \dots, K-1;$$

(118)

$$j_g^k(r) = -D_g \frac{\partial \varphi_g^k}{\partial z} \Big|_{z=z_k} = -D_g \frac{\partial \varphi_g^{k-1}}{\partial z} \Big|_{z=z_k} \quad k = 1, \dots, K-1 \quad (119)$$

$$\theta C_{gk}^R \varphi_g^k(R, z) = -\gamma D_g \frac{\partial \varphi_g^k}{\partial r} \Big|_{r=R} \quad (120)$$

$$\frac{\partial \varphi_g^k}{\partial r} \Big|_{r=0} = 0 \quad (121)$$

$$C_{gK}^T \varphi_g^K(r, h) = -\alpha D_g \frac{\partial \varphi_g^K}{\partial z} \Big|_{z=h} \quad (122)$$

and

$$\beta C_{gk}^B \varphi_g^k(r, 0) = +\eta D_g \frac{\partial \varphi_g^k}{\partial z} \Big|_{z=0} \quad (123)$$

with $g = 1, \dots, G$ in all these equations. These equations correspond to Eqs 5-14. Hence, φ_g^k and j_g^k provide the solution to the variational problem. The equations for φ_g^k and j_g^k could be obtained in a similar manner by varying $\varphi_g^k(r, z)$ and $\beta_g^k(r)$. Now our synthesis assumptions are

$$u_g^k(r, z) = \sum_{n=1}^{N_g^k} H_{gn}^k(r) T_{gn}^k(z) \quad (124)$$

and

$$u_g^{k*}(r, z) = \sum_{n=1}^{M_g^k} H_{gn}^{k*}(r) T_{gn}^k(z) \quad (125)$$

where, as before, $H_{gn}^k(r)$ and $H_{gn}^{k*}(r)$ are the known trial functions and $T_{gn}^k(z)$ and $T_{gn}^{k*}(z)$ are the unknown functions to be determined.

Finally, the functions $\beta_g^k(r)$ and $\alpha_g^k(r)$ are defined as

$$\beta_g^k(r) = \sum_{n=1}^{M_g^k} B_{gn}^k(r) b_{gn}^k \quad k = 1, \dots, K-1, \quad g = 1, \dots, G. \quad (126)$$

and

$$a_g^k(z) = \sum_{n=1}^{M_g^k} A_{gn}^k(z) a_{gn}^k, \quad k = 1, \dots, K-1, \quad g = 1, \dots, G. \quad (127)$$

Substituting Eqs. 124-127 in Eq. 116 and using the same vector convention as before, we obtain the reduced functional J' . The reduced functional is,

$$\begin{aligned} J' [T_{gn}^k(z), T_{gm}^{k*}(z), b_{gn}^k, a_{gm}^k] = & \sum_{g=1}^G \left\langle \sum_{k=1}^K \int_{z_{(k-1)}}^{z_k} 2\pi dz \left(\frac{dT_g^{k*}}{dz} [D_g^k], \frac{dT_g^k}{dz} \right. \right. \\ & + \bar{T}_g^{k*} \left\{ [L_g^k]_1 + [B_g^k]_1 + [C_g^k]_1 \right\} \bar{T}_g^k - \sum_{g'=1}^{G-1} \bar{T}_{g'}^{k*} [\Sigma_{g'g}^k] \bar{T}_g^k \\ & - \sum_{g=1}^G \bar{T}_g^{k*} \left\{ [x_g(v\Sigma_f)_g]^k \right\} \bar{T}_g^k \Bigg\rangle + \sum_{g=1}^G \left\langle \sum_{k=1}^{K-1} \left[2\pi \bar{a}_g^k \left\{ [A_g^k]_1, \bar{T}_g^k(z_k) \right. \right. \right. \\ & - \left. \left. [\bar{A}_g^{(k+1)}]_1, \bar{T}_g^{(k+1)}(z_k) \right\} + 2\pi \left\{ \bar{T}_g^{k*}(z_k) [B_g^k]_1 - \bar{T}_g^{(k+1)*}(z_k) [\bar{B}_g^{(k+1)}]_1 \bar{b}_g^k \right\} \right. \\ & + 2\pi \left\{ \alpha C_g^K \bar{T}_g^{K*}(h) [W_g^K]_1 \bar{T}_g^K(h) + (\alpha-1) \left[\bar{T}_g^{K*} [D_g^K]_1, \frac{dT_g^K}{dz} \right]_{z=h} \right. \\ & + \left. \bar{T}_g^K [D_g^K]_1, \frac{dT_g^{K*}}{dz} \right]_{z=h} + \eta B_g^B \bar{T}_g^{B*}(0) [W_g^1]_1 \bar{T}_g^1(0) \\ & \left. \left. + \eta(1-\theta) \left[\bar{T}_g^1 [D_g^1]_1, \frac{dT_g^1}{dz} \right]_{z=0} + \left[g [D_g^1]_1, \frac{dT_g^{1*}}{dz} \right]_{z=0} \right\} \right\rangle \quad (128) \end{aligned}$$

Now the matrices $[D_g^k]$, $[L_g^k]$, $[\Sigma]$, $[\Sigma_{g'g}^k]$, $[x_g(v\Sigma_f)_g]^k$, $[A_g^k]$, $[\bar{A}_g^{(k+1)}]$, $[B_g^k]$, $[\bar{B}_g^{(k+1)}]$, $[W_g^K]$ and $[W_g^1]$ are defined in a manner similar to the definitions given Eqs. 28-38. The only difference is that

the integrands are functions of r , not z , the limits are 0 to R , not 0 to h , and the differential is $r dr$ instead of dz . $[C_g^k]$ is given by the expression

$$R\theta \left[\gamma C_{gk}^R H_{gm}^{k*}(R) H_{gn}^k(R) + (\gamma - 1) D_g(R, z) \left[H_{gm}^{k*}(R) H_{gn}^k \Big|_{r=R} + H_{gm}^{k*} \Big|_{r=R} H_{gn}^k(R) \right] \right. \\ \left. + \left(H_{gm}^{k*} \Big|_{r=0} H_{gn}^k \Big|_{r=0} \right) \right] = C_{gk}^{mn}(z). \quad (129)$$

The presence of the r in each integral does not bother the algorithm used in computing the integrals, it simply has the effect of adding an extra z to the integrands, which makes the integrands as defined in Section 7 third-degree polynomials.

Now integrating the double gradient term of Eq. 128 by parts, we have

$$J' = \sum_{g=1}^G \left[\sum_{k=1}^K \left\langle \int_{z_{(k-1)}}^{z_k} 2\pi dz \bar{T}_g^{k*} \left(-\frac{d}{dz} \left\{ [D_g^k]_1 \frac{d\bar{T}_g^k}{dz} \right\} + \left\{ [A_g^k]_1 + [Z_g^k]_1 + [C_g^k]_1 \right\} \bar{T}_g^k \right. \right. \right. \\ \left. \left. + \sum_{g'=1}^{g-1} [Z_{g'g}^k]_1 \bar{T}_{g'}^{k+1} + \sum_{g'=1}^g \left\{ [X_g(\sqrt{z})]_{g'}^k \right\} \bar{T}_{g'}^{k+1} \right) \right\rangle + 2\pi \sum_{k=1}^{K-1} \left\langle \bar{T}_g^{k+1} [A_g^k]_1 \bar{T}_g^k(z_k) \right. \\ \left. - [A_g^{(k+1)}]_1 \bar{T}_g^{(k+1)}(z_k) \right\rangle + \bar{T}_g^{k*}(z_k) \left\{ [D_g^k]_1 \frac{d\bar{T}_g^k}{dz} \Big|_{z=z_k} + [B_g^k]_1 \bar{T}_g^k \right\} \\ \left. - \bar{T}_g^{(k+1)*}(z_k) \left\{ [D_g^{(k+1)}]_1 \frac{d\bar{T}_g^{(k+1)}}{dz} \Big|_{z=z_k} + [B_g^{(k+1)}]_1 \bar{T}_g^{(k+1)} \right\} \right\rangle \\ + 2\pi \left\{ \alpha C_{gk}^T \bar{T}_g^{k*}(h) [W_g^K]_1 \bar{T}_g^K(h) + (\gamma - 1) + 1 \right\} \left[\bar{T}_g^*(h) [D_g^K]_1 \frac{d\bar{T}_g^K}{dz} \Big|_{z=h} \right. \\ \left. + (\gamma - 1) \left[\bar{T}_g^K(h) [D_g^K]_1 \frac{d\bar{T}_g^{K*}}{dz} \Big|_{z=h} \right] + \beta C_{gk}^B \bar{T}_g^{k*}(0) [W_g^1]_1 \bar{T}_g^1(0) \right. \\ \left. + \left[\pi(1 - \beta) + 1 \right] \left[\bar{T}_g^1(0) [D_g^1]_1 \frac{d\bar{T}_g^1}{dz} \Big|_{z=0} + \pi(1 - \beta) + \bar{T}_g^1(0) [D_g^1]_1 \frac{d\bar{T}_g^{1*}}{dz} \Big|_{z=h} \right] \right\} \quad (130)$$

Now using matrix notation and arbitrarily varying independent-variable functions $T_{gn}^k(z)$ and a_{gn}^k , we obtain the following conditions for stationariness, with $T_{gn}^k(z)$ and b_{gn}^k replaced by $\bar{\psi}_{gn}^k(z)$ and $\bar{j}_{gn}^k$, respectively. The reduced Euler equation is

$$\frac{d}{dz} \left([D_g^k]_1 \frac{d\bar{\psi}_g^k}{dz} \right) + [\Sigma_{Rg}^k]_1 \bar{\psi}_g^k - \sum_{g=1}^{G-1} [\Sigma_{gR}^k]_1 \bar{\psi}_g^k - \lambda \sum_{g=1}^G \{ [\chi_g(v\Sigma_f)_g]^k \} \bar{\psi}_g^k = 0 \quad (131)$$

in volumes V_k , $k = 1, 2, \dots, K$, where

$$[\Sigma_{Rg}^k]_1 = [L_g^k]_1 + [\Sigma_g^k]_1 + [C_g^k]_1$$

At the synthesis-region interfaces z_k ,

$$[A_g^k]_1 \bar{\psi}_g^k(z_k) = [\bar{A}_g^{(k+1)}]_1 \bar{\psi}_g^{(k+1)}(z_k), \quad (132)$$

$$\left[D_g^k \right]_1 \frac{d\bar{\psi}_g^k}{dz} \Big|_{z=z_k} + [B_g^k]_1 \bar{\psi}_g^k = 0, \quad (133)$$

and

$$\left[\bar{D}_g^{(k+1)} \right]_1 \frac{d\bar{\psi}_g^{(k+1)}}{dz} \Big|_{z=z_k} + [\bar{B}_g^{(k+1)}]_1 \bar{\psi}_g^k = 0. \quad (134)$$

At the reactor top,

$$\left[D_g^K \right]_1 \frac{d\bar{\psi}_g^K}{dz} \Big|_{z=h} + \zeta C_{gK}^T [W_g^K]_1 \bar{\psi}_g^K(h) = 0, \quad (135)$$

and at the reactor bottom,

$$\left[D_g^K \right]_1 \frac{d\bar{\psi}_g^K}{dz} \Big|_{z=0} - \eta C_{gK}^B [W_g^K]_1 \bar{\psi}_g^K(0) = 0. \quad (136)$$

The adjoint equations could be obtained in a similar fashion.

The finite-difference approximation that will be used to solve the system of equations (Eqs. 131-136) is essentially the same as that previously used. The reactor domain in this case is the interval $[0, h]$ with the mesh $0 = p_0 < \dots < p_I = h$. Now in any interval $[p_i, p_{i+1}]$, we have a differential system consisting of the interface conditions of Eq. 65 along with the equation

$$-\frac{d}{dz}\left(D_i \frac{d\psi}{dz}\right) + (\Sigma_R)_i \psi = I_i(z)$$

Generating Q_i and integrating the above equation with respect to z yields, in the same fashion as before, the matrices

$$\left. \begin{aligned} G_i &= B_i Q_i^{-1} A_i, \quad N_i = N_{i+1}, \quad i = 1, 2, \dots, I-1; \\ H_i &= \hat{B}_{i-1} Q_i^{-1} A_{i-1}, \quad N_i = N_{i-1}, \quad i = 2, 3, \dots, I; \\ E_i &= B_i Q_i^{-1} A_i + \hat{B}_{i-1} Q_{i-1}^{-1} A_{i-1} + V_i \Sigma_R i, \quad i = 2, 3, \dots, I-1; \\ E_i &= B_i Q_i^{-1} A_i + D_i \left[\Pi D_i + \frac{\rho}{2} C_{g1}^B \delta_i W_i \right]^{-1} \rho C_{g1}^B W_i + V_i \Sigma_R i; \\ \text{and} \\ E_I &= D_I \left[\rho D_I + \frac{\rho}{2} C_{gK}^T \delta_I W_I \right]^{-1} C_{gK}^T W_I + \hat{B}_{I-1} Q_{I-1}^{-1} A_{I-1} + V_I \Sigma_R I \end{aligned} \right\} \quad (137)$$

where

$$\delta_i = \rho_i - \rho_{i-1}, \quad W_i = [W_g^K], \quad W_i = [W_g^i], \quad \text{and } V_i = \delta_i.$$

From this point the discussion reverts to that for Eqs. 69-76 and we have solved for the unknown functions $T_{gn}^k(z)$.

For Case b, the variational functional to be used is

$$\begin{aligned} J[u_g^k(x, y), u_g^{k*}(x, y), \alpha_g^k(y), \beta_g^k(y)] &= \sum_{k=1}^K \left\langle \int_{V_k} \sum_{g=1}^G \left\{ \nabla u_g^{k*} \cdot D_g \nabla u_g^k \right. \right. \\ &\quad \left. \left. + u_g^{k*} \left[\Sigma_{Tg} u_g^k - \sum_{g'=1}^{G-1} \Sigma_{g'g} u_{g'}^k - \lambda x_g \sum_{g'=1}^G (v \Sigma_f)_{g'} u_{g'}^k \right] \right\} dx dy \right\rangle \\ &- \sum_{k=1}^{K-1} \left\langle \int_0^h \left\{ \sum_{g=1}^G \alpha_g^k \left[u_g^{(k+1)}(x_k, y) - u_g^k(x_k, y) \right] + \left[u_g^{(k+1)*}(x_k, y) \right. \right. \right. \\ &\quad \left. \left. - u_g^{k*}(x_k, y) \right] \beta_g^k \right\} dy \right\rangle + \sum_{g=1}^G \left[\sum_{k=1}^K \left\langle \int_{x(k-1)}^{x_k} \left\{ \alpha_g^T C_{gk}^T u_g^{k*}(x, h) u_g^k(x, h) \right. \right. \right. \end{aligned} \quad (138)$$

(Contd.)

$$+ (\alpha - 1) \left\{ u_g^{k*}(x, h) D_g \frac{\partial u_g^k}{\partial y} \Big|_{y=h} + u_g^k(x, h) D_g \frac{\partial u_g^{k*}}{\partial y} \Big|_{y=h} \right\} dx$$

$$+ \pi \int_{x(k-1)}^{x_k} \left\{ \beta C_{gk}^B u_g^{k*}(x, 0) u_g^k(x, 0) + (1 - \beta) \left[u_g^{k*}(x, 0) D_g \frac{\partial u_g^k}{\partial y} \Big|_{y=0} \right. \right.$$

$$\left. + u_g^k(x, 0) D_g \frac{\partial u_g^{k*}}{\partial y} \Big|_{y=0} \right\} dx + \beta \int_a^h \left\{ \gamma C_{gk}^R u_g^{k*}(a, y) u_g^K(a, y) \right.$$

$$\left. + (\gamma - 1) \left[u_g^{K*}(a, y) D_g \frac{\partial u_g^K}{\partial x} \Big|_{x=a} + u_g^K(a, y) D_g \frac{\partial u_g^{K*}}{\partial x} \Big|_{x=a} \right] \right\} dy$$

$$+ \epsilon \int_0^h \left\{ \delta C_{g1}^L u_g^{1*}(0, y) u_g^1(0, y) + (1 - \delta) \left[u_g^{1*}(0, y) D_g \frac{\partial u_g^1}{\partial x} \Big|_{x=0} \right. \right.$$

$$\left. + u_g^1(0, y) D_g \frac{\partial u_g^{1*}}{\partial x} \Big|_{x=0} \right\} dy$$

(Contd.)
(138)

Upon varying u_g^{k*} and u_g^k , the functional yields Eqs. 8-13 as the conditions of stationariness, where x_k replaces R_k , y replaces z , x replaces r , and a replaces R , while in place of Eq. 14 we have

$$\delta C_{g1}^L \phi_g^{k*}(0, y) = + \epsilon D_g \frac{\partial \phi_g^1}{\partial x} \Big|_{x=0} \quad (139)$$

The synthesis assumptions used are Eqs. 23-26 with x and y instead of r and z . Substituting these synthesis assumptions in Eq. 138 yields the reduced functional Eq. 128 with 2π , α , ζ , C_{gk}^T , η , β , C_{g1}^B , and z replaced by 1, θ , γ , C_{gk}^R , ϵ , δ , C_{g1}^L , and x , respectively. The matrices are defined by Eqs. 28-38 with z replaced by y . The technique for solving this reduced functional is the same as for Eq. 128, since Eq. 130 and all that follows is applicable.

C. General Program Description

I. Capabilities

a. Geometry Types. The module SYN2D is capable of handling three geometry types, X-Y, R-Z, and Z-R. The first type, X-Y, indicates a rectangular reactor being synthesized in the X direction with the trial functions as functions of Y. In the second case, R-Z, the reactor is a right circular cylinder being synthesized in the radial direction with the trial functions as functions of Z. The Z-R geometry is again a right circular cylinder; however, in this case the direction of synthesis is the Z-axis, while the trial functions are functions of R. In both the R-Z and Z-R geometries, there is no dependence upon θ .

b. Boundary-condition Types. The following boundary conditions can be applied at the external faces of the reactor. The ability of the code to satisfy these conditions will ultimately depend upon the trial functions supplied and how well they can be combined. The acceptable boundary conditions for each face are

$$(1) \quad \varphi = 0;$$

$$(2) \quad \frac{\partial \varphi}{\partial n} = 0;$$

and

$$(3) \quad \frac{\partial \varphi}{\partial n} + \frac{B}{D} \varphi = 0,$$

where D is the diffusion coefficient at the edge, and B is a user-supplied constant which can vary with group and refined region.

In X-Y geometry there are four faces at which boundary conditions are applied, and any of the above may be used. However, in R-Z for the fourth face on the left ($R = 0$), and in Z-R for the first face on the bottom ($R = 0$), only condition type 1 may be applied. In the direction of synthesis, the same boundary condition must be applied over the entire face for a given group, but may vary from group to group. In a nonsynthesis direction, the boundary condition used may vary with each group and refined region. For a discussion of refined regions, see Section 1.g below.

c. Calculation Type. The only calculation of which SYN2D is capable is a real homogeneous k -effective calculation.

d. Energy-group Structure. Only downscattering is allowed; however, there is no limit to the number of groups that are downscattered into from each energy group.

e. Fission-spectrum Type. Only χ vectors can be presently handled. Thus χ is only a function of composition and group.

f. Buckling. Buckling in the Z direction can be accepted when the geometry type is $X \cdot Y$. Otherwise, no buckling is allowed.

g. Synthesis-region Structure. Synthesis-region boundaries may be placed anywhere; however, they must lie on mesh-cell boundaries.

Fig. 2. Typical Synthesis Region

At least two synthesis regions must be defined. There is no upper limit to the number of regions defined.

Consider a particular synthesis region. It will be bounded on the left and right by synthesis boundaries and will contain intervals in the synthesis direction. Now consider the one-dimensional cuts obtained from each interval by moving in the direction perpendicular to the synthesis direction. (Figure 2 illustrates a typical synthesis region containing four reactor regions, R_1 , R_2 , R_3 , and R_4 , plus the

imposed mesh structure.) When two adjacent cuts differ, a change has taken place. A group of contiguous intervals which produce the same cut is called a refined region. Figure 2 contains 7 intervals and five refined regions. The intervals defining the five refined regions are 1, 2, 3-4, 5, 6-7. The union of the refined regions for all synthesis regions yields the set of refined regions for the problem.

h. Trial-function Structure. The real and adjoint trial functions on the input-data sets are paired together, depending upon their position on each library. Thus, the n th real trial function is paired with the n th adjoint trial function. The number of trial functions used can be varied by group within a synthesis region and can also vary between different synthesis regions, subject to Section 1.1 below. This scheme provides the user with a great deal of flexibility.

i. Synthesis Interface Conditions. Since each synthesis region is independent of all other regions, some relationship between regions must be imposed in order to solve the finite-difference equations. The two interface conditions listed below provide the relations necessary to calculate the mixing functions. The asymmetric interface condition considers each synthesis boundary by using the trial functions in the region to the left only as the connecting-link. The symmetric interface condition considers the trial functions on both sides of the synthesis boundary. This second condition provides a symmetry that would not be present in the first case. It does, however, require that there be a constant number of trial functions used for each group and all synthesis regions. No such restriction is imposed when the asymmetric interface is used.

A more complete discussion of these interface conditions appears in Section 6.

j. Region and Composition Assignments The definition of the mesh structure, placement of the reactor regions, and assignment of the various compositions to these regions are handled by the ARC System module GNIP (NU1002) using the A NIP data set.

k. Restart Capabilities When running problems of a similar nature, one can achieve large savings in time if certain data sets are saved. The boundary conditions, geometry-mesh structure, regions, compositions, and composition-to-region assignments, the code-generated trial-function libraries, the code-computed partial integrals, and the code-calculated mixing functions all can be saved for later runs. Subsequent runs then need change only selected data sets. See Section 2 g (below) for more information on this feature.

l. Problem Size and Storage Requirements The synthesis module is capable of running quite large problems which require considerable core storage. All storage is allocated dynamically. This allows great flexibility in the sizes of various arrays. The main core storage available is approximately 60,000-70,000 double words. This varies, depending upon the data sets open and their buffer sizes. The bulk core available is approximately 125,000 double words, but it can also vary.

Listed below are formulas for the core requirements of the largest arrays in each section of the computation.

<u>Formula</u>	<u>Section</u>
$N[1(\max(G, K)) + GK]$	Problem-dependent trial-function library generation
$J(8N + 2) + N^2R$	Partial integral generation
$N^2[3I + 2RR + 4K + \overline{RR}(2G - I) + R]$	Finite-difference matrix generation
$N[1(1 + 2N + 2G) + NG]$	Power iteration
$J(I + N) + GIN$	Flux reconstitution
$J(2I + 1) + R(9G + 8) + 7G + I$	Standard output calculation

Here,

G is the number of energy groups

I is the number of points in the synthesis direction,

J is the number of points in the trial-function direction,

K is the number of synthesis regions,

N is the $\max(N_k)$, where N_k is the largest number of real trial functions per synthesis region k taken over all energy groups.

R is the number of reactor regions.
 RR is the number of refined regions

and

$\overline{RR}$ is the $\max_k(RR_k)$, where RR_k is the number of refined regions in synthesis region k .

Now given a particular problem, the values of these parameters are either known or can be easily calculated. Substitution into the above formulas yields six numbers. The largest of these numbers, L , represents the core requirements of the largest arrays. Addition of 5-10% more core for smaller arrays should yield the number of double words required by the POINTNTR container array. Thus for a problem in which $G = 20$, $I = J = 50$, $K = 10$, $N = 5$, $R = 20$, $RR = 25$, and $\overline{RR} = 4$, a main core POINTNTR allocation of 14,500 double words with a bulk core allocation of zero double words would be sufficient.

The algorithms used above indicate minimal core requirements. Increasing the size of the container array above this figure will increase the efficiency of POINTNTR and may allow the trial functions to be held in core for the library generation step.

2. User Options

a. Interface Conditions. Either the asymmetric or symmetric interface conditions may be used. See Section 1.1 above.

b. Adjoint Option. The user can specify that the real trial functions be used for both the real and adjoint trial functions or he can specify both real and adjoint trial functions.

c. Print Options. The user can specify the amount of printout he wishes to receive. There are three levels. The first provides minimal output only, the last provides a total output capability. The second provides a fairly extensive but not total capability. The user should experiment to see which type he really requires. (See Section G.2 for a more detailed explanation of the options.) The less printout required, the faster the module will run.

d. Error-print Options. Should an error be suspected, the user can print out the POINTNTR arrays which hold the various matrices and check their values using the POINTNTR debugging flag.

e. Preprocessing Option. This option provides the capability of generating the partial integrals and trial-function libraries and then terminating the calculation. These data sets would then be used in a later run. (See Section 2.g below.)

f. Boundary-matrix Option. In a given synthesis region the boundary conditions applied at the reactor top face, bottom face, or both faces could be $\phi = 0$. In this case, some of the trial functions (both real and adjoint of each pair) may be known to satisfy the condition on the face or faces where it applies. The user can indicate these functions, and the code when it calculates the associated boundary matrices will use this fact. This can eliminate some of the computational error and produce a slightly better k-effective.

g. Restart Options. Section 1.k above indicates the capabilities the user has to save data sets. The saving of ARC System data sets BC and GEOM will save a call to the GNIP module by the path STP008. Saving the data set XS.C.MIN saves calls to the modules INHOMG and HOMOG. If SYN2D is being used independently of the path STP008, then the user's path will dictate whether these data sets can be saved.

Since XS.C.MIN involves only the composition cross-section data, it may be changed independently of other data sets. BC contains the boundary condition information, while GEOM contains the mesh-structure and region-structure information. Changes in either of these types of data will require a call to GNIP. FR.TG contains the calculated mixing functions. Saving this data set will be of aid if the job runs out of time, in which case the code need not start the iterations from the beginning but can pick up from where it left off. Data sets LIB.REAL, LIB.MIX, and LIB.ADJT are the code-generated trial-function libraries. These data sets need be regenerated only when changes in the user-supplied trial functions for the problem are made. Finally, data set LIB.PART contains the partial integrals which are generated from the three previous data sets. A set of partial integrals is generated for each synthesis region. The sub-intervals over which the partial integrals are generated are defined as the union of the top and bottom coordinates of the reactor regions in each refined region, which lie in each synthesis region. Referring to Fig. 2, there are three partial integrals required for each integration. The integration is performed over the following sets of intervals: 1-2, 3-4, and 5. See Section D below for additional information on restarting problems.

3. Data Sets Used

<u>Upper-interface Data Sets</u>	<u>Records Read</u>
A.SYN2D, Module-dependent BCD Input	All
BC, Boundary Condition Specifications	All
FR.TG, Mixing Functions	All
FR.TRIAL, User-input Real Synthesis Trial-function Library	All required
FA.TRIAL, User-input Adjoint Synthesis Trial-function Library	All required

Upper-interface Data SetsRecords Read

GEOM, Geometry Data	All
LIB.ADJT, Code-refined Adjoint Trial-function Library	All
LIB.MIX, Code-refined Real Trial-function Library	All
LIB.PART, Partial Integrals	All
LIB.REAL, Code-refined Real Trial-function Library	All
XS.C.MIN, Macroscopic Composition Cross Sections	All

The data sets BC and GEOM are usually generated from data in data set A.NIP. XS.C MIN is generated from data in A NIP and in the macroscopic group cross-section data set XS.ISO.

Lower-interface Data SetsRecords Written

FR.D2, Two-dimensional Real Group Fluxes	All
FR.PN, Power-normalized Real Regional Group Fluxes	All
FR.TG, Mixing Functions	All
LIB.ADJT, Code-refined Adjoint Trial-function Library	All
LIB.MIX, Code-refined Real Trial-function Library	All
LIB.PART, Partial Integrals	All
LIB.REAL, Code-refined Real Trial-function Library	All

D. Description of Program Execution

The SYN2D program is invoked, along with the other ARC System computational modules listed in Section A.2 above, by standard path STP008. This standard path is executed using the catalogued procedure ARCSP008, which contains the job control language and data-set definitions needed for execution. This section defines the input to the catalogued procedure ARCSP008, describes the procedure, and tells the user options available through the procedure.

It then briefly describes the path STP008 and its options.

1. Catalogued Procedure Description

a. Definition and Listing of the Linkages of the Catalogued Procedure. Following is a listing of the JCLs required to execute the catalogued procedure ARCSP008, which calls the ARC System standard path STP008.

```
//JOB CARD
//ACCOUNTING CARD
//SETUP DDNAME=DUMMY,DEVICE=2314,ID=DISK1
//SETUP DDNAME=DUMMY,DEVICE=2314,ID=DISK1
// EXEC ARCSP008
//          PATRIAL=ADJOINT,DS,NAME',PATVOL=DISK1,
//          PATRIAL=REAL,DS,NAME',PATVOL=DISK1,
//          MACRS1=MXSN,FILE1,MACRS2=MXSN,FILE2,MACRVOL=DISK1
//          OTHER SYMBOLIC PARAMETERS WHICH MAY BE REQUIRED
//SYSDUMP DD UNIT=(CTC,DEFER)
```

```

OTHER DD CARDS FOR DSRN 42-65 AS REQUIRED BY NUMBER OF ENERGY GROUPS
//STP008,SYNIN DD *
BLOCK=OLD
DATASET=XS.ISO
DATASET=FR.TRIAL
DATASET=FA.TRIAL
  OTHER DATA SETS WHICH ARE OLD
BLOCK=STP008
DATASET=A.SYN2D
  BCD FOR DATA SET A.SYN2D
DATASET=A.NIP
  BCD FOR DATA SET A.NIP
/*

```

The JOB CARD should have a minimum main core region size of 550K, but need have no bulk core allocation unless quite large problems are being run. If the type 02 card of data set A.SYN2D requests a bulk allocation of n , then a bulk core allocation of $8n$ should be put on the JOB CARD.

Setup cards will be required for the disks containing the microscopic cross-sections, for the input trial-function libraries, and possibly for those data sets being saved.

The symbolic parameters listed give the data sets that must be old, along with their disk locations. ADJOINT.DS.NAME and REAL.DS.NAME must be replaced by the adjoint and real trial-function data-set names. MXSN.FILE1 and MXSN.FILE2 should be replaced by the names of the microscopic cross-section data-set files. Other symbolic parameters can be added as desired to save new data sets or to use old ones. Refer to Section D.1.b below and C.1.k above.

Information on how to add the extra scratch data sets and when to add them is contained in Section D.1.b below.

Only data sets that are referenced in the symbolic parameter list can appear under the BLOCK=OLD heading. These data sets, which have previously been created, should be referenced in this section by their standard ARC names. Note that although the disposition of a data set is old, the information the data set contains is not necessarily pertinent to this problem. Hence, the data set will be referenced in the symbolic parameter list; it will not be referenced in the BLOCK=OLD list. Finally, only the following additional data sets should ever appear in this list (BLOCK=OLD): BC, GEOM, LIB ADJT, LIB.MIX, LIB.PART, LIB.REAL, and FR.TG.

b. Description of Catalogued Procedure Deck. Following is a listing of the catalogued procedure ARCSPO08.

```

//ARCSPU08 PROC ADJTLIB='ELIHADJT',ADJTDSP='(,DELETE)',ADJTVOL=SCRWTD, X
//      BC='RCUNDI',BCDSP='(,DELETE)',BCVOL=SYSSCR, X
//      COMPS1='EXSECT1',COMPDSP='(,DELETE)',COMPVOL=SCRONE, X
//      COMPS2='EXSECT2',DISKNV=78, X
//      FATRIAL='CFATRIAL',FATVOL=SCRONE, X
//      FLXTWD='CFRLOZ',FLXDSP='(,DELETE)',FLXVOL=SYSSCR, X
//      FRTRIAL='CFRTRIAL',FRTVOL=SCRONE, X
//      GEOM='GEMMDS',GEOMDSP='(,DELETE)',GEOMVOL=SCRWTD, X
//      MICRXS1='GMICRXS1',MICRXS2='GMICRXS2',MICRVOL=SCRONE, X
//      MIXLIB='CLIBGIX',MIXDSP='(,DELETE)',MIXVOL=SCRWTD, X
//      PARTLIB='CLIBPART',PARTDSP='(,DELETE)',PARTVOL=SCRONE, X
//      REALLIB='CLIBREAL',REALDSP='(,DELETE)',REALVOL=SYSSCR, X
//      TGRF='CFRLOTG',TG DSP='(,DELETE)',TGVOL=SYSSCR
//STP008 EXEC PGM=STP008
//STEPLIB DD DSN=DDDISKND,MODLIB,UNIT=DISK,DISP=(SHR,PASS), X
//      VOL=SER=DISK&DISKND
//FT03F001 DD DSN=SYSIN,THIS CARD DEFINES INPUT DATA SET
//FT04F001 DD UNIT=(CTC,DEFER), X
//      DCB=(RECFM=VBSA,LRECL=137,BLKSIZE=1311) X
//      THIS CARD DEFINES THE OUTPUT DATA SET
//FT09F001 DD UNIT=2314,SPACE=(CYL,(1,1)), X
//      DCB=(RECFM=VBS,LRECL=84,BLKSIZE=3364) X
//      ARC SYSTEM DS360 CORRESPONDENCE
//FT11F001 DD DSN=CANIP,UNIT=DISK,SPACE=(CYL,(1,1)), X
//      DCB=(RECFM=VBS,LRECL=84,BLKSIZE=1604) X
//      GENERAL NEUTRONICS INPUT DATA
//FT12F001 DD DSN=CASYN200,UNIT=DISK,SPACE=(TRK,(1,1)), X
//      DCB=(RECFM=VBS,LRECL=84,BLKSIZE=7601) X
//      2-D SYNTHESIS MODULE DEPENDENT DATA SET
//FT13F001 DD DSN=CBHUMOG,UNIT=DISK,SPACE=(CYL,(1,1)), X
//      DCB=(RECFM=VBS,LRECL=X,BLKSIZE=3460) X
//      MATERIAL AND COMPOSITION SPECIFICATIONS
//FT14F001 DD DSN=CBC,UNIT=DISK,SPACE=(TRK,(1,1)), X
//      DCB=(RECFM=VBS,LRECL=X,BLKSIZE=304) X
//      VOL=SER=CBVOL,DISP=CHCDSP X
//      BOUNDARY-CONDITION SPECIFICATIONS
//FT15F001 DD DSN=CFATRIAL,UNIT=DISK,DISP=(OLD,KEEP), X
//      VOL=SER=CFATVOL X
//      USER SUPPLIED ADJOINT TRIAL FUNCTIONS
//FT16F001 DD DSN=CFLXTWD,UNIT=DISK,SPACE=(CYL,(3,1),RLSE), X
//      DCB=(RECFM=VBS,LRECL=X,BLKSIZE=7294) X
//      VOL=SER=CFLXVOL,DISP=CFLXDSP X
//      REAL TWO DIMENSIONAL FLUX DATA SET
//FT17F001 DD DSN=CFRPN,UNIT=DISK,SPACE=(CYL,(1,1)), X
//      DCB=(RECFM=VBS,LRECL=X,BLKSIZE=1604) X
//      POWER NORMALIZED REGION FLUXES
//FT18F001 DD DSN=CTGR,UNIT=DISK,SPACE=(CYL,(1,1)), X
//      DCB=(RECFM=VBS,LRECL=X,BLKSIZE=7004) X
//      VOL=SER=CTGVOL,DISP=CTGDSP X
//      MIXING FUNCTIONS DATA SET
//FT19F001 DD DSN=CFRTRIAL,UNIT=DISK,DISP=(OLD,KEEP), X
//      VOL=SER=CFRTVOL X
//      USER SUPPLIED REAL TRIAL FUNCTIONS
//FT20F001 DD DSN=CGEOM,UNIT=DISK,SPACE=(CYL,(1,1)), X
//      DCB=(RECFM=VBS,LRECL=X,BLKSIZE=804) X
//      VOL=SER=CGEOMVOL,DISP=CGEOMDSP X
//      GEOMETRY SPECIFICATIONS DATA SET
//FT21F001 DD DSN=CADJTLIB,UNIT=DISK,SPACE=(CYL,(3,1),RLSE), X
//      DCB=(RECFM=VBS,LRECL=X,BLKSIZE=7204) X
//      VOL=SER=CAJTV,DISP=CAJTDSP X
//      EUD GENERATED ADJOINT TRIAL FUNCTION LIBRARY
//FT22F001 DD DSN=CMIXLIB,UNIT=DISK,SPACE=(CYL,(3,1),RLSE), X

```

```

//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=7204), X
//          VOL=SER=GMIXVOL,DISP=GMIXFSP X
//          CODE GENERATED REAL TRIAL FUNCTIONS (MATRIX GENERATION) X
//FT23F001 DD DSN=GPART1B,UNIT=DISK,SPACE=(CYL,(3,1),RLSE), X
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=7172), X
//          VOL=SER=GPARTVOL,DISP=GPARTDSP X
//          CODE GENERATED PARTIAL INTEGRALS
//FT24F001 DD DSN=GREAL1B,UNIT=DISK,SPACE=(CYL,(3,1),RLSE), X
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=2164), X
//          VOL=SER=GREALVOL,DISP=GREALDSP X
//          CODE GENERATED REAL TRIAL FUNCTION LIBRARY
//FT25F001 DD DSN=GSCRO01,UNIT=DISK,SPACE=(CYL,(1,3),RLSE), X
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=7060), X
//          VOL=SER=SCRONE X
//          SCRATCH DATA SET CONTAINS H MATRICES
//FT26F001 DD DSN=GSCRO02,UNIT=DISK,SPACE=(CYL,(2,3),RLSE), X
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=4324), X
//          VOL=SER=SCRTW0 X
//          SCRATCH DATA SET CONTAINS FISSION MATRICES
//FT27F001 DD DSN=GSCRO03,UNIT=DISK,SPACE=(CYL,(1,3),RLSE), X
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=7060), X
//          VOL=SER=SCRTW3 X
//          SCRATCH DATA SET CONTAINS V & U INVERSE MATRICES
//FT28F001 DD DSN=GSCRO04,UNIT=DISK,SPACE=(CYL,(2,3),RLSE), X
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=4324), X
//          VOL=SER=SYSSCR X
//          SCRATCH DATA SET CONTAINS SCATTERING MATRICES
//FT29F001 DD DSN=GSPCICN0,UNIT=DISK,SPACE=(76,1), X
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=76) X
//          CODE INDEPENDENT CONSTANTS SPECIFICATIONS
//FT32F001 DD DSN=GCOMPXS1,UNIT=DISK,SPACE=(CYL,(1,1)), X
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=1028), X
//          VOL=SER=GCOMPVOL,DISP=GCOMPDSR X
//          FILE 1 OF DATA SET XS.C.MIN
//FT32F002 DD DSN=GCOMPXS2,UNIT=DISK,SPACE=(CYL,(1,1)), X
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=7172), X
//          VOL=SER=GCOMPVOL,DISP=GCOMPDSR X
//          FILE 2 OF COMPOSITION CROSS SECTION DATA SET XS.C.MIN
//FT34F001 DD DSN=GMICRXS1,UNIT=DISK,DISP=SHR,VOL=SER=GMICRVOL X
//          THIS IS FILE 1 OF THE DATA SET XS.ISO DEFINING X
//          ISOTOPE CROSS SECT DNS
//FT34F002 DD DSN=GMICRXS2,UNIT=DISK,DISP=SHR,VOL=SER=GMICRVOL X
//          THIS IS FILE 2 OF THE DATA SET XS.ISO DEFINING X
//          ISOTOPE CROSS SECT DNS
//FT35F001 DD DSN=GXSISO2A,UNIT=DISK,SPACE=(CYL,(1,1)), X
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=644) X
//          FILE 1 OF DATA SET XS.ISO2 CONTAINS A SHORTENED FORM OF X
//          THE DATA SET XS.IS
//FT35F002 DD DSN=GXSISO2B,UNIT=DISK,SPACE=(CYL,(1,1)), X
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=7172) X
//          FILE 2 OF DATA SET XS.ISO2
//FT37F001 DD DSN=GXSMMIN,UNIT=DISK,SPACE=(CYL,(1,1)), X
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=7172) X
//          DATA SET XS.M.MIN CONTAINS MATERIALS CROSS SECTIONS
//FT40F001 DD UNIT=DISK,SPACE=(CYL,(2,1),RLSE),DISP=(DELETE), X
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=7204) X
//FT41F001 DD UNIT=DISK,SPACE=(CYL,(2,1),RLSE),DISP=(DELETE), X
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=7204) X
//FT42F001 DD UNIT=DISK,SPACE=(CYL,(2,1),RLSE),DISP=(DELETE), X
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=7204) X
//FT43F001 DD UNIT=DISK,SPACE=(CYL,(2,1),RLSE),DISP=(DELETE), X
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=7204) X

```

```
//FT44F001 DD UNIT=DISK,SPACE=(CYL,(2,1),RLSE),DISP=(,DELETE), X
//          DCB=(RECFM=VBS,LRECL=X,RLKSIZE=7204) X
//FT45F001 DD UNIT=DISK,SPACE=(CYL,(2,1),RLSE),DISP=(,DELETE), X
//          DCB=(RECFM=VBS,LRECL=X,RLKSIZE=7204) X
//          DATA SETS NUMBERED 40-45 & 25-28 ARE REQUIRED TO GENER- X
//          ATE THE CODE GENERATED TRIAL FUNCTION DATA SETS. X
//          ONE DATA SET FOR EACH ENERGY GROUP. HENCE FOR MUPE X
//          THAN TEN GROUPS ADD OTHER DATA SETS SIMILAR TO # 40, X
//          OTHERWISE DO NOTHING. X
//          EX. //STPOOR,FTNNFOO1 DD ETC. WHERE N=46,47,.... X
```

Section 1.a above outlined the general procedure for executing this catalogued procedure. All that now remains is to add any required scratch data sets and to make the appropriate substitutions of data-set names, volumes, and dispositions in the symbolic parameter list. Listed below are the catalogued procedure symbolic data-set names, followed by their ARC System names and the data-set reference numbers to which they apply.

Symbolic Name	ARC Name	DSRN
ADJTLIB	LIB.ADJT	21
BC	BC	14
COMPXS1	XS.C.MIN file 1	32 file 1
COMPXS2	XS.C.MIN file 2	32 file 2
FATRIAL	FA.TRIAL	15
FLXTWOD	FR.D2	16
FRTRIAL	FR.TRIAL	19
GEOM	GEOM	20
MICRXS1	XS.ISO file 1	34 file 1
MICRXS2	XS.ISO file 2	34 file 2
MIXLIB	LIB.MIX	22
PARTLIB	LIB.PART	23
REALLIB	LIB.REAL	24
TGER	R.TG	18

The two files of XS.C.MIN and ISO must always be paired.

In addition to the data sets referenced in Section 1.a, these are the only data sets that may be permanently saved. Now, for example, suppose that the ARC System data set FR.TG is to be saved under the name of REAL MIXING on a disk name DISK18. Then the following card would be inserted in the symbolic parameter list (see Section 1.a above):

```
//TGER=REAL MIXING TGDSP=(NEW,KEEP),TGVOL=DISK18,X
```

If this data set had been previously defined on this disk, this same card would be used, but the word "NEW" would be replaced by "OLD." The symbolic parameters TGDSP and TGVOL can be found in the symbolic parameter list at the beginning of the catalogued procedure. They are used to give the

data-set disposition and disk identifier, respectively. This same technique is used for any other data set. The catalogue procedure already contains the default options that ordinarily make these data sets temporary.

c. Scratch Data Sets. This catalogued procedure is presently designed to run problems having six energy groups. If problems containing more than six energy groups are to be run, then extra scratch data sets must be added when generating the ARC System data sets LIB ADJT, LIB.MIX, and LIB.REAL. One scratch data set is required for each energy group in excess of six groups. The data-set reference numbers should be in sequence and begin at number 42. Refer to the procedure listing for the proper form of the required DD cards.

2. Path Description

a. Listing and Notes. Presently only one path exists that calls the synthesis module. This path (STP008) is listed below.

```

MEMBER NAME SYN2DPTM
C PATH STP008 00000100
  REAL*8 PATH,XSC,DSNAME(240),BC,GEOM 00000200
  REAL*4 TIME2,TIME1,DTIME 00000300
  DATA XSC/XS.C.MIN//,GEOM/GEOM //,BC/BC // 00000400
  DATA DSNAME/ 00000500
  1 A,NIP //,A.SYN2D //,B.HOMOG //,BC //,FA.TRIAL//,FR.D2 //,00000600
  2 AFR,PN //,FR.TG //,FR.TRIAL//,GEOM //,LIB.ADJT//,LIB.MIX //,00000700
  3 LIB.PART//,LIB.REAL//,SCROO1 //,SCROO2 //,SCROO3 //,SCROO4 //,00000800
  4 SP.CICN //,SP.CRIT //,XS.C.AUX//,XS.C.MIN//,XS.DELAY//,XS.ISD //,00000900
  5 XS.ISQ2 //,XS.M.AUX//,XS.M.MIN//, 00001000
  A // 00001100
  TIME2=TIME1+DTIME 00001200
  PRINT 20 00001300
  CALL SYSTEM(DSNAME) 00001400
  CALL BCDD(S' STP008 ',N1) 00001500
  CALL SNIFF(BC,N1,0) 00001600
  IF(N1.GE.0) GO TO 5 00001700
  CALL SNIFF(GEOM,N3,0) 00001800
  IF(N3.GE.0) GO TO 5 00001900
  PRINT 25,BC,N1,GEOM,N3 00002000
  GO TO 7 00002100
  5 CALL LINK('NU1002 ') 00002200
  7 CALL SNIFF(XSC,N2,0) 00002300
  IF(N2.GT.0) GO TO 10 00002400
  CALL LINK('NU1001 ') 00002500
  CALL LINK('NUC001 ',4,0,0,0,1) 00002600
  GO TO 9 00002700
  10 CONTINUE 00002800
  PRINT 30,N2 00002900
  9 CALL LINK('AJC005 ') 00003000
  TIME1=TIME1+DTIME 00003100
  DTIME=(TIME2-TIME1)/6000. 00003200
  IF(DTIME.LE.0.01) DTIME=DTIME+14 .0 00003300
  PRINT 50,DTIME 00003400
  PRINT 60 00003500
  20 FORMAT(' MODULE STP008 HAS BEEN ENTERED. ') 00003600
  25 FORMAT(' DATA SET ',AB,' IS ASSUMED TO EXIST ON DSN ',13,/) 00003700
  30 FORMAT(' 1. 20X, DATA SET XS.C.MIN EXISTS? ') 00003800
  1 '0',20X,'MACROSCOPIC C POSITION X-SECTIONS ARE ASSUMED? ' 00003900
  2 21X,'TO BE ON DATA SET REFERENCE NUMBER 13' 00004000
  50 FORMAT(' TIME FOR THE EXECUTION OF STP008 IS ',F10.4,' MINUTES. ') 00004100
  60 FORMAT(' MODULE STP008 HAS JUST BEEN EXITED FROM. ') 00004200
  RETURN 00004300
  END 00004400

```

The data sets referred to in the data statement containing the DSNNAME array are not all required by SYN2D. They exist because they are required by other modules called by the path, or for future expansion and modification purposes. The extra data sets, listed in order, are SP.CICN, SP.CRIT, XS.C.AUX, XS.DELAY, XS.ISO, XS.M.AUX, and XS.M.MIN.

B. ARC System Modules Called by This Path The following ARC System modules are referenced by this path. Their system names and arguments are listed, followed by their common names in brackets.

NUC001 (4 0,0;0,1)	[HOMOG]
NUI001	[INHOMOG]
NUI002	[GNIP]
AJC005	[SYN2D]

C. Path Options. The only options presently available enable the user to skip the modules HOMOG and INHOMOG and GNIP if the data sets XS.C.MIN or GEOM and BC are old. If both GEOM and BC are old data sets, then the module GNIP will not be called. Should both be new or if only one is old, GNIP will be called to regenerate these data sets. The combination of INHOMOG and HOMOG is called if XS.C.MIN is new, otherwise no call is made. In most cases it will be advantageous for the user to employ the catalogued procedure when running test cases using the path. (Refer to Section D.1 above.)

E. Module-dependent Input to SYN2D

The module-dependent input to module SYN2D consists of the BCD data set A.SYN2D, which provides for the user options described in Section C. This section displays the specifications for this data set.

A.SYN2D Data-set Specifications

<u>01</u>	(12X,10A6)	Proble Title
	Col 13-72	Proble title
		This will appear on each page of output. A different title should be used with each problem run.
<u>02</u>	(12X,816)	Proble Options
	Col 13-18	Maxim number of iterations
	19-24	Probl type option on interface condition
		1 A ymmetric interface
		2 S ymmetric interface

- 25-30 Output option
 0 Limited output
 1 Normal output (normally used value)
 2 All program output
- 31-36 Debugging print option (POINTR)
 0 No POINTR printout (normally used value)
 1 Standard full printout
 2 Debugging dumps printout
 3 Full debugging printout
- 38-42 Size of main core POINTR array (if 0 or negative the default is 60000)
- 43-48 Size of bulk core POINTR array (if negative none is requested, if 0 the default is 120,000)
- 49-54 Adjoint option
 0 Real and adjoint trial functions are different
 1 The program should use the real trial functions also as adjoints
- 03 (12X,5E12.5) Outer-iteration Convergence Criteria
 Col 13-24 Flux-difference convergence criterion, on sum of the absolute value of the flux difference divided by the normed sum of the absolute values of the flux (10^{-6} is recommended)
- 25-36 Flux-bounds convergence criterion, on $(\bar{\lambda} - \lambda)$ (10^{-5} is recommended)
- 37-48 k-effective difference convergence criterion (10^{-7} is recommended)
- 49-60 Power-normalization factor for burnup
- 04 (12X,10I6) Synthesis-region Options
 Col 13-18 Number of synthesis regions
 19-24 The maximum number of real trial functions in any synthesis region for any group
 25-30 Preprocess option (generates partial integrals and program-used function libraries)
 0 Generates the above and runs a complete case
 1 Generates the above and terminates run
- 05 (12X,5E12.5) Synthesis-region Boundaries
 Col 13-24 First synthesis boundary (which must be greater than zero)
 25-36 Second boundary

37-48 Third boundary
 49-60 Fourth boundary
 61-72 Fifth boundary

Additional boundaries start on the next card and continue as above with five per card. Only the internal boundaries are required

****NOTICE If a synthesis boundary that is not on a mesh line is input, the code will move this boundary toward the left to the first mesh line that it encounters, and this mesh line will be the synthesis boundary. If more than one boundary is placed between two adjacent mesh lines, the first is handled as above and the remaining points are moved to the right to correspond one-to-one with mesh lines. This feature is quite useful, for suppose we wish to have two mesh lines in the interval (0,1) and we wish to have synthesis boundaries at $1/3$ and $2/3$. These numbers cannot be input to machine accuracy, but if we input 0.4 and 0.7 the code will assume that we meant $1/3$ and $2/3$.

06A (12X,1016) Synthesis-region Trial-function Assignments

Col 13-18 G_{final}
 19-24 Number of real functions for this region for the range of $G_{initial}$ to G_{final} (note $G_{initial}$ is either 1, or the previous G_{final} plus 1 if previous G_{final} was not equal to G_{MAX})
 25-30 Zeroing options
 This option is used if one of the boundary conditions applied in this synthesis region is $\psi = 0$ and certain trial functions used in this region satisfy this condition. This ensures that no contribution to the boundary matrices is made unless applicable:
 0 This option is not used
 1 Use this option in the BC matrix generation

06B (12X,1016) Real and Adjoint Trial-function Choices

Col 13-18 First function number on library
 19-24 Second function number on library
 25-30 Third function number on library
 31-36 Fourth function number on library
 37-42 Fifth function number on library
 43-48 Sixth function number on library

- 49-54 Seventh function number on library
 55-60 Eighth function number on library
 61-66 Ninth function number on library
 67-72 Tenth function number on library

If there are more functions, the above procedure is repeated on succeeding cards. When the last function number has been given, the rest of card is left blank.

06C (12X,10I6) Trial-function Boundary-condition Options

This card is used only if columns 25-30 on the 06A card are not zero. It has the same format as the 06B cards. A zero is placed in the corresponding column if the function satisfies the boundary condition $\psi = 0$; otherwise, a 1 appears.

Cards 06A, 06B, and 06C must be used for every synthesis region (06C only where applicable). The set for region two follows the set for region one, etc. If in any region G_{final} is not equal to G_{MAX} , then we use another 06A card, where the new G_{final} is greater than the previous G_{final} , followed by the 06B and if necessary the 06C card, and we repeat this as many times as necessary until $G_{final} = G_{MAX}$ on the 06A card. Then we proceed to the next synthesis region.

07 (12X,8I6) Scratch Data-set Reference Numbers

These scratch data sets are used by the code in generating the trial function library, exclusive of SCR001, SCR002, SCR003, and SCR004. Since one scratch data set is needed for each energy group (NGROUP - 4), scratch data set reference numbers must be given.

Col 13-18 First DSRN (if using the catalogued procedure, use 41)

Col 19-24 Second DSRN (if using the catalogued procedure, use 42)

Continue in this fashion until all the data-set reference numbers needed are given. When the catalogued procedure is used, succeeding data-set reference numbers should be 43, 44, etc. Eight numbers appear on each card.

The card type number, as given above, can appear in the first two or three columns of each card. It is not read by the SYN2D program, which expects the cards to be in the order described.

F. Error Messages

This section describes the error messages that can be generated by this program. The messages are listed under the names of the subroutines generating them, which appear in alphabetical order. Error messages generated by subroutine entry points are listed under the name of the corresponding subroutine.

For each error, the complete error message is listed, followed by descriptions of the significance of the message to the user and of the action taken by the program when the error is encountered.

BCONDS

Message: THE BOUNDARY CONDITION APPLIED AT THE REACTOR
aaaaaaaa FOR REFINED REGION rrrr IS NOT
HOMOGENEOUS

ERROR NUMBER 1 IN SUBROUTINE BCONDS

Significance: The letters aaaaaaaaa will be replaced by 'TOP' or 'BOTTOM' to indicate which reactor face is not correct; rrrr will be the number of the refined region in which the improper boundary condition was encountered. The allowable boundary conditions are $\phi = 0$, $\phi' = 0$, and $\phi + (B/D)\phi' = 0$, where B is a user-supplied constant and D is the diffusion coefficient at the reactor face. The boundary condition applied had a nonzero number on the right of the equal sign.

Action Taken: Execution is terminated.

Message: THE BOUNDARY CONDITION APPLIED AT THE REACTOR
aaaaaaaa FOR REFINED REGION rrrr IS NOT A PROPER
TYPE

ERROR NUMBER 1 IN SUBROUTINE BCONDS

Significance: The boundary condition applied was homogenous, but of an incorrect type. Refer to the previous message.

Action Taken: Execution is terminated.

Message: THE BOUNDARY CONDITION APPLIED AT THE REACTOR
aaaaaaaa FOR REFINED REGION rrrr IS NOT CONSISTENT
FOR THE ENTIRE REGION.

THE BOUNDARY CONDITION APPLIED AT THE REACTOR
aaaaaaaa FOR REFINED REGION rrrr IS NOT
HOMOGENEOUS

ERROR NUMBER 1 IN SUBROUTINE BCONDS

Significance: A change in boundary condition has taken place in this refined region. Refer to the first message.

Action Taken: Execution is terminated.

Message: THE BOUNDARY CONDITION APPLIED AT THE REACTOR
 aaaaaaaa FOR REFINED REGION rrrr IS NOT CONSISTENT
 FOR THE ENTIRE REGION

THE BOUNDARY CONDITION APPLIED AT THE REACTOR
 aaaaaaaa FOR REFINED REGION rrrr IS NOT A PROPER
 TYPE

ERROR NUMBER 1 IN SUBROUTINE BCONDS

Significance: A change in the boundary condition has taken place in this refined region. Refer to the second message

Action Taken: Execution is terminated.

CALC1

Message: *****DRRMN FOR REFINED REGION rrr IS SINGULAR. NO
 INVERSE.

ERROR NUMBER 1 IN SUBROUTINE CALC1

Significance: Determinant $[D_{gk}(r)] = 0$ where r is in refined region rrr. Therefore we cannot find its inverse or compute Ω . The trial functions used in the synthesis region containing refined region r are not linearly independent.

Action Taken: Execution is terminated.

Message: *****OMEGA IS SINGULAR FOR INTERVAL iii, HENCE NO
 INVERSE.

ERROR NUMBER 2 IN SUBROUTINE CALC1

Significance: Determinant $\Omega_{iii} = 0$, hence Ω^{-1} does not exist.

Action Taken: Execution is terminated.

COFGEN

Message: DATA SET LIB.PART IS NOT CONSISTENT WITH THIS
 PROBLEM

ERROR NUMBER 1 IN SUBROUTINE COFGEN

Significance: One of the following errors was detected on data set
 LIB.PART:

- a. The number of synthesis regions does not agree with this problem.
- b. The number of energy groups does not agree with this problem.

- c The time key on this data set does not agree with the key on the code-generated data sets LIB ADIT, LIB MIX, and LIB REAL. The time key is used to ensure that data sets LIB ADIT, LIB MIX, and LIB REAL were all generated in the same run.

Either use the correct version of LIB PART, or regenerate it.

Action Taken: Execution is terminated

Message: DATA SET LIB PART IS NOT CONSISTENT WITH THIS PROBLEM.

ERROR NUMBER 2 IN SUBROUTINE COFGEN

Significance: Either the number of partial integrals per synthesis region necessary to generate the complete integral is not correct, or there are not enough partial integrals to generate all the required integrals for all synthesis regions and energy groups.

Either use the correct version of LIB PART, or regenerate it.

Action Taken: Execution is terminated

Message: THE BOUNDARY CONDITIONS APPLIED ON THE aaaaaaaa FOR GROUP gggg ARE NOT CONSISTENT

ERROR NUMBER 3 IN SUBROUTINE COFGEN

Significance: The name aaaaaaaa can only be 'LEFT' or 'RIGHT', while gggg indicates the energy group in which the error was encountered. The boundary condition along the indicated face can change only with energy group and not with position on the face.

Action Taken: Execution is terminated

Message: CAN NOT INVERT THE MATRIX L IN THE SYMMETRIC OPTION HENCE DM CAN NOT BE GENERATED FOR SYNTHESIS REGION kkk GROUP gggg

ERROR NUMBER 4 IN SUBROUTINE COFGEN

Significance: The matrix L calculated for the synthesis boundary between synthesis region kkkk and synthesis region kkkk + 1 for energy group gggg when using the symmetric option is singular. Refer to Section II B above for more information on this option. The trial functions used in both regions may be dependent. A better choice of trial functions in these two regions should be possible.

Action Taken: Execution is terminated

D2DOUT

Message ERROR NUMBER 1 IN SUBROUTINE D2DOUT

Significance Trace-back error from other routines in the output segment

Action Taken Execution is terminated

DSRNCK

Message TROUBLE ON DSRN nnnn INFORMATION IS NOT CONSISTENT WITH THIS PROBLEM.

DS CLAIMS GMAX=gggg IMAX=jjj KMAX=kkkk and NGKMX llll BUT GMAX gggg IMAX jjj KMAX=kkkk AND NGKMX=llll

ERROR NUMBER 1 IN SUBROUTINE DSRNCK

Significance The data set LIB ADJT on DSRN nnnn does not agree with this problem. The information obtained from A.NIP and A.SYNZD gives the number of energy groups (gggg'), the number of trial-function values (jjj'), the number of synthesis regions (kkk'), and the maximum number of trial functions used in any synthesis region (lll'). These numbers do not agree with the values found on LIB.ADJT. If kkkk is negative, then the inverse of $\hat{K}$ could not be computed and hence the matrix 3MN could not be calculated.

Either use correct data sets, or regenerate the correct data sets.

Action Taken Execution is terminated

Message NUMBER OF TRIAL FUNCTIONS PER SYNTHESIS REGION AND GROUP ON DSRN nnnn DOES NOT AGREE WITH THIS PROBLEM

ERROR NUMBER 2 IN SUBROUTINE DSRNCK

Significance The data set LIB ADIT on DSRN nnnn does not contain the proper arrangement of trial functions for this problem.

Either use correct data sets, or regenerate the correct data sets.

Action Taken Execution is terminated

Message DSRN nnnn AND DSRN mmmmm ARE NOT CONSISTENT

ERROR NUMBER 3 IN SUBROUTINE DSRNCK

Significance The time keys for the two data sets are not the same, indicating that they were not created in the same run. Refer to normal output information previously printed to identify these data sets.

Either use the correct data sets, or regenerate them

Action Taken	Execution is terminated
<u>IFXVOL</u>	Refer to error message for IFXVOL
<u>IGPCAL</u>	Refer to error message for IGPCAL
<u>IFXNRM</u>	
Message	ERROR NUMBER 1 SUBROUTINE IFXNRM
Significance	Geometry type is not XY, RZ, ZR, or R0.
Action Taken	The power normalization factor for burnup is not computed
<u>IFXVOL</u>	
Message	Group ggg
	ERROR NUMBER 1 IN SUBROUTINE FXVOL
Significance	ggg is the record number at which an I/O error was detected when reading the external source data set. This error should never appear for this module.
Action Taken	None
<u>IGPCAL</u>	
Message	ERROR NUMBER 1 IN SUBROUTINE GPCAL
Significance	Error trace-back from REGBAL.
Action Taken	Execution is terminated.
<u>LIKCEL</u>	
Message	ERROR NUMBER 1 IN SUBROUTINE LKCELL
Significance	Boundary condition type other than 0, 1, or 2 has been specified on the right, left, top, or bottom boundary. The value of 1 indicates which boundary.
Action Taken	Execution is terminated.
<u>IVOL</u>	
Message	ERROR NUMBER 1 IN SUBROUTINE IVOL
Significance	Geometry type is not XY, RZ, ZR, OR R0.
Action Taken	IVOL, the function value, is set to 1, and normal return is made
Message	ERROR NUMBER 1 IN SUBROUTINE VOL
Significance	Geometry type is not XY, RZ, ZR, or R0.
Action Taken	VOL, the function value, is set to 0, and normal return is made

LIB

Message *****SNIFF UNABLE TO LOCATE FR TRIAL

ERROR NUMBER 1 IN SUBROUTINE LIB

Significance This data set could not be located by ARC System subroutine SNIFF. This implies that the data set has not been written.

Action Taken Execution is terminated

Message *****SNIFF UNABLE TO LOCATE FA TRIAL

ERROR NUMBER 2 IN SUBROUTINE LIB

Significance This data set could not be located by ARC System subroutine SNIFF. This implies that the data set has not been written.

Action Taken Execution is terminated

Message *****THE TRIAL FUNCTION LIBRARIES ARE NOT CONSISTENT

ERROR NUMBER 3 IN SUBROUTINE LIB

TROUBLE ON DSRN llll

IT HAS nnnnn FUNCTIONS AND CLAIMS

GMAX=ggggg AND JMAX=jjjjj

BUT GMAX=ggggg AND JMAX=jjjjj

TROUBLE ON DSRN kkkkk

IT HAS mmmmm FUNCTIONS AND CLAIMS

GMAX=lllll AND JMAX=ppppp

BUT GMAX=ggggg AND JMAX=jjjjj

ERROR NUMBER 7 IN SUBROUTINE LIB

Significance The number of re l trial functions nnnnn on DSRN llll is not the same as the number of adjoint trial functions mmmmm on DSR kkkk

Action Taken Execution is terminated.

Message ERROR NUMBER IN SUBROUTINE LIB

*****UNABLE TO LOCATE LIB.REAL OR LIB.ADJT OR
LIB.MIX IN PATH DSNAME ARRAY

Significance One of these data sets could not be located by ARC System subroutine SNIFF. This implies that the data set has not been written

Action Taken Execution is terminated.

Message *****UNABLE TO FIND ALL FLUX FUNCTIONS FOR GROUP ppp
REGION kkk CHECK 06B INPUT

ERROR NUMBER 5 IN SUBROUTINE LIB

TROUBLE ON DSRN kkkkk

IT HAS nnnnn FUNCTIONS AND CLAIMS

GMAX=ggggg AND JMAX=jjjj

BUT GMAX=ggggg and JMAX=jjjj

ERROR NUMBER 7 IN SUBROUTINE LIB

Significance: The module is unable to find all the required flux trial functions for energy group ggggg, synthesis region kkkkk. Trouble could be on 06B input cards, or the user-supplied library could be in error

Action Taken: Execution is terminated

Message: TROUBLE ON DSRN kkkkk

IT HAS nnnnn FUNCTIONS AND CLAIMS

GMAX=ggggg AND JMAX=jjjj

BUT GMAX=ggggg AND JMAX=jjjj

ERROR NUMBER 7 IN SUBROUTINE LIB

Significance: The nnnnn trial functions on data-set reference kkkkk are not consistent with this problem. The data set has ggggg energy groups and jjjj points per function, while this problem has ggggg energy groups and jjjj points in the nonsynthesis direction. Make the data set and problem consistent, and resubmit.

Action Taken: Execution is terminated.

MTGEN1

Message *****D FOR REFIN D REGION 1 IS SINGULAR FOR GROUP ggg
HENCE INVER DOESN'T EXIST

Significance: Determinant of $D_{g1}(1) = 0$. Therefore its inverse $(D_{g1})^{-1}$ does not exist. The trial functions used are probably not linearly independent.

Action Taken: Execution is terminated.

Message *****B.C MATRIX NOT INVERTIBLE VALUE=vv (1 IS LEFT,
LESS THAN 1. IGH)

ERROR NUMBER 2 IN SUBROUTINE MTGEN1

Significance: The determinant of $[C_1 D_{gk}(r) + 0.5 C_2 \delta W_{gk}] = 0$, hence the inverse does not exist. If vv is 1 then $k = 1$, $\delta = \delta_1$, $r = 1$, and this matrix is needed to compute E_1 . If vv is less than 1, then $k = K$, $\delta = \delta_{IMAX}$, and r is the last refined region. The computation is for E_{IMAX} . Note that C_1 and C_2 vary with group and reactor face.

Action Taken: Execution is terminated.

Message: ERROR NUMBER 3 IN SUBROUTINE MTGEN1.

Significance: The vertical boundary condition given is $DC \cdot C_1 \phi' + C_2 \phi = C_3$. C_3 should be zero and is not. C_3 is ignored, i.e., assumed to be zero.

Action Taken: None (execution continues).

Message: ERROR NUMBER 4 IN SUBROUTINE MTGEN1.

Significance: The vertical boundary condition required is $DC \cdot C_1 \phi' + C_2 \phi = 0$, where DC is the diffusion coefficient. (This is a type 2 boundary condition unless C_1 or C_2 is zero.) User has input wrong boundary condition type for the values of C_1 and C_2 that the code receives. Program assumes that the type 2 boundary condition was implied.

Action Taken: None (execution continues).

LKCELL: Refer to error messages for subroutine ILKCELL.

MTGEN2

Message: *****E(1) IS SINGULAR

ERROR NUMBER 1 IN SUBROUTINE MTGEN2

Significance: $DET(E_1) = 0$, hence $U_1^{-1} = E_1^{-1}$ does not exist. The energy group in which this occurs can be deduced from the previous printout.

Action Taken: Execution is terminated.

Message: *****U(11) IS SINGULAR

ERROR NUMBER 11 IN SUBROUTINE MTGEN2

Significance: $DET(U_{11}) = 0$, hence U_{11}^{-1} does not exist. The energy group in which this occurs can be deduced from the previous printout.

Action Taken: Execution is terminated.

PCOMP

Message *****SEARCH CALCULATED A NEGATIVE aaaaaaaa VALUE

COMPOSITION SEARCH TERMINATED

ERROR NUMBER 1 IN SUBROUTINE PCOMP

where aaaaaaaa represents a cross-section type:

DIF COEF, REMOVAL, FISSION, NU FISSION, CHI MTRX,
or SCATTER.

Significance: In adding the modifier composition to the original composition on a search pass, the search calculated a negative value or values of some cross-section type or types (only the most recently calculated type being indicated). Presently, module SYN2D has no search capability, hence, this message should never appear.

Action Taken: The concentration search is terminated, without output of data sets.

PROCES

Message: DATA SET LIB.PART IS NOT IN THE PATH DSNAME
ARRAY

ERROR NUMBER 1 IN SUBROUTINE PROCES.

Significance: This data set could not be found by ARC System subroutine SNIFF. This implies that the data set has not been written.

Action Taken: Execution is terminated.

PRTBC

Message: *****CALCULATION TYPE IS K CALC BOUNDARY CONDITIONS
INDICATE CALCULATION SHOULD BE INHOMOGENEOUS

Significance: One or more inhomogeneous boundary or interface conditions have been defined, and the calculation is not a source type. Either the boundary conditions or the calculation type is in error. No inhomogeneous capability presently exists for SYN2D.

Action Taken: Execution is terminated.

RBND

Message: *****DATA SET BC NOT FOUND

ERROR NUMBER 1 IN SUBROUTINE RBND

Significance: This data set could not be found by ARC System subroutine SNIFF. This implies that the data set has not been written.

Action Taken: Execution is terminated.

Message ERROR NUMBER 2 IN SUBROUTINE RBNDG
 Significance The number of boundary conditions defined is less than 2.
 Action Taken Execution is terminated.

Message ERROR NUMBER 3 IN SUBROUTINE RBNDG
 Significance If the number of horizontal boundary conditions is zero and geometry is not R0 full periodic, then an error exists.
 (Module SYN2D has no R0 capability)

Action Taken Execution is terminated

Message ERROR NUMBER 4 IN SUBROUTINE RBNDG

Significance Error return from PRIBC

Action Taken Execution is terminated.

RCDEP

Message *****A.SYN2D NOT FOUND BY SNIFF

ERROR NUMBER 1 IN SUBROUTINE RCDEP

Significance This data set could not be found by ARC System subroutine SNIFF. This implies that the data set has not been written.

Action Taken Execution is terminated

Message POINTR STORAGE COULD NOT BE ALLOCATED.

ERROR NUMBER 2 IN SUBROUTINE RCDEP

Significance The container array size requested on the A.SYN2D type 02 card exceeds the space available. Increase the region sizes on the job card, and/or decrease the array sizes on the type 02 card.

Action Taken Execution is terminated.

Message *****ALL REQUIRED SCRATCH DATA SETS ARE NOT IN THE PATH

ERROR NUMBE 3 IN SUBROUTINE RCDEP

Significance All four scratch ata sets SCR001, SCR002, SCR003, and SCR004 were not found in the path DNAME array.

Action Taken Execution is terminated.

RCOMP

Message *****DATA SET XS.C IN NOT FOUND

ERROR NUMBE 1 IN SUBROUTINE RCOMP

Significance: This data set could not be found by ARC System subroutine SNIFF. This implies that the data set has not been written.

Action Taken: Execution is terminated.

Message: ERROR NUMBER 2 IN SUBROUTINE RCOMP

Significance: This end of the first file of XS.C.MIN was not found, and the second file thus could not be read.

Action Taken: Execution is terminated.

Message: ERROR NUMBER 3 IN SUBROUTINE RCOMP

Significance: Data set XS DELAY could not be found by ARC System subroutine SNIFF. This implies that the data set has not been written.

Action Taken: Execution is terminated.

Message: ERROR NUMBER 4 IN SUBROUTINE RCOMP

Significance: * The number of families, NFAM, defined in XS.C MIN was zero, and the kinetics option indicates that delayed data are desired for an α -calculation. (Note that module SYN2D contains no kinetics capability)

Action Taken: Execution is terminated.

Message: ERROR NUMBER 5 IN SUBROUTINE RCOMP

Significance: Trace-back for previously encountered error.

Action Taken: Execution is terminated.

Message: ERROR NUMBER 6 IN SUBROUTINE RCOMP

Significance: Error in reading record type 1 of data set XS.C.MIN.

Action Taken: Execution is terminated.

Message: ERROR NUMBER 8 IN SUBROUTINE RCOMP

Significance: Data set A.KI 2D is not present for kinetics option 3. (Note that kinetics options are not implemented for SYN2D.)

Action Taken: Execution is terminated.

RGEOM

Message: ERROR NUMBER 1 IN SUBROUTINE RGEOM

Significance: This data set could not be found by ARC System subroutine SNIFF. This implies that the data set has not been written.

Action Taken: Execution is terminated.

Message ERROR NUMBER 2 IN SUBROUTINE RGEOM

Significance: The geometry type number is not 4, 5, 6, or 8. It may be a one-dimensional type (1, 2, or 3), may be XY geometry with 45° symmetry (7), which is not available, or may be meaningless. The geometry type selected in data set A.NIP (card type 3, cols. 13-18) should be checked.

Action Taken: Execution is terminated

RGROUP

Message: *****TRANSPORT CROSS-SECTION = 0 DIFFUSION COEFFICIENT = 1.0E +15

FOR COMPOSITION aaaaaaaa, GROUP iii

Significance: A transport cross section of zero for this composition and group was read from data set XS.C.MIN, and hence the diffusion coefficient $D_{c,g} = 1/(3\sigma_{TR})$ could not be calculated. The diffusion coefficient is set to 1

Action Taken: Processing continues.

Message: *****ERROR IN READING RECORD 03 OF XS.C.MIN ON DSRN iii
ERROR NUMBER 1 IN SUBROUTINE RGROUP

Significance: An error was encountered in attempting to read a record of type 3 for some composition.

Action Taken: Execution is terminated.

RMESH

Message: *****ERROR IN RECORD iii OF DATA SET ON DSRN nnnn
ERROR NUMBER 1 IN SUBROUTINE RMESH

Significance: A read error was encountered when trying to read the data set GEOM.

Action Taken: Execution is terminated.

RSDEF

Message: *****INVALID GEOMETRY TYPE

ERROR NUMBER 1 IN SUBROUTINE RSDEF

Significance: Geometry type is not 2-D geometry type XY, RZ, or ZR.

Action Taken: Execution is terminated

Message: ERROR NUMBER 2 IN SUBROUTINE RSDEF

Significance: An error has been committed in POINTR. Probably more space was requested than was available. Increase the size of the container array, or decrease the problem size, and resubmit.

Action Taken: Execution is terminated.

Message: THE THREE DATA SETS LIB REAL LIB ADJT LIB MIX
MUST BE EITHER ALL NEW OR ALL OLD BUT NOT
MIXED.

ERROR NUMBER 3 IN SUBROUTINE LIB

Significance: The disposition of these three data sets was not consistent.
SNIFF detected some as new and some as old. Refer to the
BCD input deck and verify the disposition of these data sets
in the BLOCK = OLD list.

Action Taken: Execution is terminated.

Message: ERROR NUMBER 4 IN SUBROUTINE RSDEF

Significance: Same as Error 2 above

Action Taken: Execution is terminated.

Message: *****AN INPUT ERROR MAY HAVE BEEN COMMITTED *****

*****CHECK STATUS OF ALL PREPROCESS DATA SETS *****

*****PROCEED WITH CAUTION.*****

Significance: The disposition, as detected by SNIFF, of the data sets
LIB ADJT, LIB REAL, and LIB MIX does not agree with
the disposition of LIB PART. If the first three are old,
no error will occur in generating LIB PART. However, if
only the last data set is old, the first three when generated
will not agree with it. Check the BCD input to verify the
disposition of these four data sets in the BLOCK = OLD list.

Action Taken: None

RVEL

Message: *****NUMBER OF GROUPS DOES NOT AGREE IN XS ISO

DSRN=iii, GMAX=jjjj, NGROUP=ggg

ERROR NUMBER 1 IN SUBROUTINE RVEL

Significance: As stated, the number of groups defined in XS.C.MIN does
not agree with the number from XS.ISO. DSRN is the data-
set number associated with XS.ISO, GMAX is the number of
groups defined in GEOM, and NGROUP is the number
defined in XS ISO

Action Taken: Execution is terminated.

Message: ERROR IN READING XS.ISO, RECORD iii
ERROR NUMBER 2 IN SUBROUTINE RVEL

Significance: System error in reading this data set. Resubmit job to see if error vanishes. Note in is the record on which an error was encountered.

Action Taken: Execution is terminated.

RXSC01

Message: *****ERROR IN READING RECORD 01 OF XS.C MIN ON
DSRN in

ERROR NUMBER 1 IN SUBROUTINE RXSC01

Significance: An error occurred in attempting to read this record.

Action Taken: Execution is terminated.

SINCAL

Message: *****KEFF=0, THEREFORE 1/KEFF IS UNDEFINED.

ERROR NUMBER 1 IN SUBROUTINE SINCAL

Significance: k-effective equals zero during iterations.

Action Taken: Execution is terminated.

Message: *****INNER PRODUCT OF OLD AND NEW FLUXES IS ZERO.
NEW KEFF IS NOT DEFINED.

ERROR NUMBER 2 IN SUBROUTINE SINCAL

Significance: $(\phi(n), \phi(n-1)) = 0$; we cannot improve our previous k-effective approximation.

Action Taken: Execution is terminated.

Message: ERROR NO UPSCATTERING IS ALLOWED. EXECUTION
TERMINATED

ERROR NUMBER 3 IN SUBROUTINE SINCAL

Significance: The iteration section is not capable of handling upscattering. Scattering cross sections must be modified to remove upscattering before the problem will run.

Action Taken: Execution is terminated.

SYNCAL

Message: *****ERROR IN INTR

ERROR NUMBER 1 IN SUBROUTINE SYNCAL

Significance: Error in POI TR. Probably PUTPNT requested more space than was available. Increase the size of the container array, or decrease the problem size, and resubmit.

Action Taken: Execution is terminated.

SYNDEF

Message *****INCORRECT NUMBER OF SYNTHESIS REGIONS

ERROR NUMBER 1 IN SUBROUTINE SYNDEF

Significance There is an error in the synthesis-region boundary input in data set A SYN2D or the X-direction interval input in data set A NIP or both, resulting in an incorrect number of synthesis regions

Action Taken Execution is terminated

Message *****ERROR IN INILT, CHECK 04 and 06. CARDS

ERROR NUMBER 2 IN SUBROUTINE SYNDEF

Significance The number of trial functions for same synthesis region and energy group is larger than the second number on the type 04 card of A SYN2D. Check to see if the trial function assignments are correct on the 06A cards. If they are not, fix them, otherwise correct the 04 card and resubmit

Action Taken Execution is terminated.

Message *****GFIN NOT PROPERLY DEFINED ON ALL OF THE 06A CARDS

ERROR NUMBER 3 IN SUBROUTINE SYNDEF

Significance The last energy-group definitions are not properly defined on the 06A cards of data set A SYN2D for the number of energy groups defined for the problem, or the ranges from the first energy group to the last energy group in each synthesis region are not correct

Action Taken Execution is terminated.

Message THE SYMMETRIC INTERFACE IMPLIES A CONSTANT NUMBER OF TRIAL FUNCTIONS

ERROR NUMBER IN SUBROUTINE SYNDEF

Significance To use the symmetric interface option, the same number of trial functions must be used for every synthesis region in a given energy group. The number of trial functions may, however, vary with energy groups

Action Taken Execution is terminated

SYNGEN

Message *****POINTR ERROR ROBABLY NOT ENOUGH STORAGE

IMAX=iii, JMAX=j j, KMAX=kkk

GMAX=ggg, NGKM =nnn, NGKPMX=mmm

RRMAX=rrrr

ERROR NUMBER (3) IN SUBROUTINE SYNGEN

Significance: "OINTR error". Probably occurred when requesting more storage than was available in array BLK. Increase the size of the container array, or decrease the problem size, and resubmit.

Action Taken: Execution is terminated.

Message: *****SNIFF UNABLE TO LOCATE 'XS.C.MIN' IN PATH DSNNAME
ARRAY

ERROR NUMBER 2 IN SUBROUTINE SYNGEN

Significance: This data set could not be located by ARC System subroutine SNIFF. This indicates that the data set has not been written.

Action Taken: Execution is terminated.

VOL Refer to the error messages for IVOL.

G. Sample Input and Output

1. Input

Listed below is the sample input to SYN2D (AJC005) using the path STP008 and the cataloged procedure ARCSP008. The format of data set A.SYN2D is described in Section II.E. The data set A.NIP is described in the ARC System documentation, ANL-7711. Data sets listed under 'BLOCK=OLD' are data sets that already exist and will be used as input to the path. The formats of FA.TRIAL and FP.TRIAL are described in Section III.E; XS.ISO is described in ANL-7711. For a detailed description of how to prepare sample input, refer to Sections II.4 and II.5. The input shown here corresponds to the sample output that follows.

Sample Input

BCD INPUT

BLOCK=OLD
 DATASET=XS.JSD
 DATASET=FR.TRIAL
 DATASET=FA.TRIAL
 BLOCK=STP008
 DATASET=A.SYN2D

01 SAMPLE,ADJOINT WEIGHTING, DISCONTINUOUS TRIAL FUNCTIONS

02 100 2 1 0 30000 -1 0
 03 1.0 E-04 1.0 E-04 1.0 E-061.1495 E+09
 04 2 2 0
 05 38.1
 06 6 2 1
 06B 1 3
 06C 0 0
 06A 6 2 1
 06B 3 5
 06C 0 0
 07 41 42

DATASET=A.NIP

01 SAMPLE,ADJOINT WEIGHTING, DISCONTINUOUS TRIAL FUNCTIONS

02
 03 51 0 0
 04 3 2 3 2
 06 CZA1 0.0 38.1 0.0 7.5962
 06 ABA11 38.1 50.8 0.0 7.5962
 06 ABA21 50.8 63.5 0.0 7.5962
 06 ABA31 63.5 76.2 0.0 7.5962
 06 CZA2 0.0 38.1 7.5962 20.0977
 06 ABA12 38.1 50.8 7.5962 20.0977
 06 ABA22 50.8 63.5 7.5962 20.0977
 06 ABA32 63.5 76.2 7.5962 20.0977
 06 CZA3 0.0 38.1 20.0977 33.1111
 06 ABA13 38.1 50.8 20.0977 33.1111
 06 ABA23 50.8 63.5 20.0977 33.1111
 06 ABA33 63.5 76.2 20.0977 33.1111
 06 CZA4 0.0 38.1 33.1111 46.20598

06	ABA14	38.1	50.8
06	ABA24	50.8	63.5
06	ABA34	63.5	76.2
06	CZA5	0.0	38.1
06	ABA15	38.1	50.8
06	ABA25	50.8	63.5
06	ABA35	63.5	76.2
06	CZA6	0.0	38.1
06	ABA16	38.1	50.8
06	ABA26	50.8	63.5
06	ABA36	63.5	76.2
06	CZA7	0.0	38.1
06	ABA17	38.1	50.8
06	ABA27	50.8	63.5
06	ABA37	63.5	76.2
06	CZB1	0.0	38.1
06	ABB11	38.1	50.8
06	ABB21	50.8	63.5
06	ABB31	63.5	76.2
06	CZB2	0.0	38.1
06	ABB12	38.1	50.8
06	ABB22	50.8	63.5
06	ABB32	63.5	76.2
06	CZC1	0.0	38.1
06	ABC11	38.1	50.8
06	ABC21	50.8	63.5
06	ABC31	63.5	76.2
06	RB11	0.0	38.1
06	RB12	38.1	50.8
06	RB13	50.8	63.5
06	RB14	63.5	76.2
06	RB21	0.0	38.1
06	RB22	38.1	50.8
06	RB23	50.8	63.5
06	RB24	63.5	76.2
06	REFRD	0.0	76.2
06	REFAX	76.2	129.54
09	X	5	38.1
09	X	2	76.2
09	Y	3	7.5962
09	Y	3	46.20598
09	Y	3	87.376
09	Y	6	123.698

33.1111	46.20598
33.1111	46.20598
33.1111	46.20598
46.20598	59.3283
46.20598	59.3283
46.20598	59.3283
46.20598	59.3283
59.3283	72.4633
59.3283	72.4633
59.3283	72.4633
59.3283	72.4633
72.4633	87.376
72.4633	87.376
72.4633	87.376
72.4633	87.376
87.376	96.9819
87.376	96.9819
87.376	96.9819
87.376	96.9819
96.9819	107.072
96.9819	107.072
96.9819	107.072
96.9819	107.072
107.072	123.698
107.072	123.698
107.072	123.698
107.072	123.698
123.698	136.9427
123.698	136.9427
123.698	136.9427
123.698	136.9427
136.9427	150.2054
136.9427	150.2054
136.9427	150.2054
136.9427	150.2054
150.2054	163.4
0.0	163.4

2	50.8	2	63.5
2	129.54		
3	20.0977	3	33.1111
3	59.3283	3	72.4633
4	96.9819	4	107.072
4	136.9427	3	150.2054

09	Y	3	163.4			
13	M1	U238	1.0			
13	M2	PU239	1.0			
13	M3	PU240	1.0			
13	M4	PU241	1.0			
13	M5	PU242	1.0			
13	M6	U235	1.0			
13	M7	O 16	1.0			
13	M8	LUPP	1.0			
13	M9	TA181	1.0			
13	M10	SS	1.0			
13	M11	NA 23	1.0			
13	M12	O 16	1.0			
14	CZA1	M1	0.72268D-02M2	0.87732D-03M3	0.38228D-03	
14	CZA1	M4	0.11058D-03M5	0.54023D-04M6	0.13058D-04	
14	CZA1	M7	0.23803D-05M8	0.58751D-03M9	0.0 D+00	
14	CZA1	M10	0.12709D-01M11	0.83235D-02M12	0.18588D-01	
14	CZA2	M1	0.72307D-02M2	0.87714D-03M3	0.38210D-03	
14	CZA2	M4	0.11082D-03M5	0.53978D-04M6	0.13105D-04	
			0.23696D-05M8	0.58383D-03M9	0.0 D+00	
14	CZA2	M10	0.12709D-01M11	0.83235D-02M12	0.18588D-01	
14	CZA3	M1	0.72407D-02M2	0.87664D-03M3	0.38164D-03	
14	CZA3	M4	0.11145D-03M5	0.53860D-04M6	0.13232D-04	
14	CZA3	M7	0.23412D-05M8	0.57417D-03M9	0.0 D+00	
14	CZA3	M10	0.12709D-01M11	0.83235D-02M12	0.18588D-01	
14	CZA4	M1	0.72573D-02M2	0.87577D-03M3	0.38084D-03	
14	CZA4	M4	0.11250D-03M5	0.53660D-04M6	0.13444D-04	
14	CZA4	M7	0.22934D-05M8	0.55815D-03M9	0.0 D+00	
14	CZA4	M10	0.12709D-01M11	0.83235D-02M12	0.18588D-01	
14	CZA5	M1	0.72800D-02M2	0.87440D-03M3	0.37964D-03	
14	CZA5	M4	0.11401D-03M5	0.53365D-04M6	0.13749D-04	
14	CZA5	M7	0.22241D-05M8	0.53585D-03M9	0.0 D+00	
14	CZA5	M10	0.12709D-01M11	0.83235D-02M12	0.18588D-01	
14	CZA6	M1	0.73117D-02M2	0.87228D-03M3	0.37774D-03	
14	CZA6	M4	0.11603D-03M5	0.52932D-04M6	0.14144D-04	
14	CZA6	M7	0.21270D-05M8	0.50700D-03M9	0.0 D+00	
14	CZA6	M10	0.12709D-01M11	0.83235D-02M12	0.18588D-01	
14	CZA7	M1	0.73574D-02M2	0.86766D-03M3	0.37362D-03	
14	CZA7	M4	0.11910D-03M5	0.52110D-04M6	0.14823D-04	
14	CZA7	M7	0.19627D-05M8	0.43734D-03M9	0.0 D+00	
14	CZA7	M10	0.12709D-01M11	0.83235D-02M12	0.18588D-01	
14	CZB1	M1	0.68689D-02M2	0.10580D-02M3	0.50307D-03	
14	CZB1	M4	0.17133D-03M5	0.70584D-04M6	0.14604D-04	

14	CZB1	M7	0.158730-05M8	0.520880-03M9	0.0 D+00
14	CZB1	M10	0.127090-01M11	0.832350-02M12	0.185880-01
14	CZB2	M1	0.693380-02M2	0.106840-02M3	0.498220-03
14	CZB2	M4	0.179150-03M5	0.689750-04M6	0.156290-04
14	CZB2	M7	0.134320-05M8	0.443440-03M9	1.4964 0-03
14	CZB2	M10	0.127090-01M11	0.832350-02M12	0.185880-01
14	CZC1	M1	0.688730-02M2	0.106270-02M3	0.504720-03
14	CZC1	M4	0.174140-03M5	0.704550-04M6	0.148980-04
14	CZC1	M7	0.153960-05M8	0.493320-03M9	0.0 D+00
14	CZC1	M10	0.127090-01M11	0.832350-02M12	0.185880-01
14	RB11	M1	0.116200-01M2	0.294550-03M3	0.977520-05
14	RB11	M4	0.189260-06M5	0.331450-08M6	0.284620-04
14	RB11	M7	0.181540-05M8	0.655750-04M9	0.0 D+00
14	RB11	M10	0.236190-01M11	0.389020-02M12	0.217130-01
14	RB21	M1	0.117560-01M2	0.201240-03M3	0.504880-05
14	RB21	M4	0.709580-07M5	0.877270-09M6	0.308370-04
14	RB21	M7	0.133150-05M8	0.255840-04M9	0.0 D+00
14	RB21	M10	0.236190-01M11	0.389020-02M12	0.217130-01
14			0.986580-02M2	0.350070-03M3	0.172920-04
14	ABA11	M4	0.457420-06M5	0.113190-07M6	0.218400-04
14	ABA11	M7	0.225270-05M8	0.922410-04M9	0.0 D+00
14	ABA11	M10	0.127090-01M11	0.832350-02M12	0.185880-01
14	ABA12	M1	0.986880-02M2	0.348160-03M3	0.170960-04
14	ABA12	M4	0.449880-06M5	0.110650-07M6	0.218910-04
14	ABA12	M7	0.224060-05M8	0.913360-04M9	0.0 D+00
14	ABA12	M10	0.127090-01M11	0.832350-02M12	0.185880-01
14	ABA13	M1	0.987670-02M2	0.343100-03M3	0.165810-04
14	ABA13	M4	0.430280-06M5	0.104100-07M6	0.220230-04
14	ABA13	M7	0.220870-05M8	0.889640-04M9	0.0 D+00
14	ABA13	M10	0.127090-01M11	0.832350-02M12	0.185880-01
14	ABA14	M1	0.988980-02M2	0.334580-03M3	0.157290-04
14	ABA14	M4	0.398450-04M5	0.937160-08M6	0.222470-04
14	ABA14	M7	0.215450-05M8	0.850580-04M9	0.0 D+00
14	ABA14	M10	0.127090-01M11	0.832350-02M12	0.185880-01
14	ABA15	M1	0.990850-02M2	0.322310-03M3	0.145370-04
14	ABA15	M4	0.355160-06M5	0.800820-08M6	0.225770-04
14	ABA15	M7	0.207580-05M8	0.796560-04M9	0.0 D+00
14	ABA15	M10	0.127090-01M11	0.832350-02M12	0.185880-01
14	ABA16	M1	0.993360-02M2	0.305430-03M3	0.129480-04
14	ABA16	M4	0.299870-06M5	0.635570-08M6	0.230170-04
14	ABA16	M7	0.196520-05M8	0.727170-04M9	0.0 D+00
14	ABA16	M10	0.127090-01M11	0.832350-02M12	0.185880-01
14	ABA17	M1	0.997130-02M2	0.279140-03M3	0.105850-04

14	ABA17 M4	0.223090-06M5	0.424540-08M6	0.237190-04
14	ABA17 M7	0.178570-05M8	0.632780-04M9	0.0 D+00
14	ABA17 M10	0.127090-01M11	0.832350-02M12	0.185880-01
14	ABB11 M1	0.100190-01M2	0.244520-03M3	0.774510-05
14	ABB11 M4	0.140770-06M5	0.226840-08M6	0.246670-04
14	ABB11 M7	0.153810-05M8	0.524100-04M9	0.0 D+00
14	ABB11 M10	0.127090-01M11	0.832350-02M12	0.185880-01
14	ABB12 M1	0.100710-01M2	0.206150-03M3	0.515420-05
14	ABB12 M4	0.769690-07M5	0.999240-09M6	0.257290-04
14	ABB12 M7	0.126580-05M8	0.406460-04M9	0.920000-03
14	ABB12 M10	0.127090-01M11	0.832350-02M12	0.185880-01
14	ABC11 M1	0.100340-01M2	0.233190-03M3	0.739120-05
14	ABC11 M4	0.134540-06M5	0.219270-08M6	0.249760-04
14	ABC11 M7	0.147010-05M8	0.488760-04M9	0.0 D+00
14	ABC11 M10	0.127090-01M11	0.832350-02M12	0.185880-01
14	RB12 M1	0.117950-01M2	0.167650-03M3	0.331870-05
14	RB12 M4	0.376600-07M5	0.368590-09M6	0.317050-04
14	RB12 M7	0.109500-05M8	0.211350-04M9	0.0 D+00
14	RB12 M10	0.236190-01M11	0.389020-02M12	0.217130-01
14	RB22 M1	0.118630-01M2	0.112640-03M3	0.163030-05
14	RB22 M4	0.131840-07M5	0.905400-10M6	0.330920-04
14	RB22 M7	0.777630-06M8	0.930330-05M9	0.0 D+00
14	RB22 M10	0.236190-01M11	0.389020-02M12	0.217130-01
14	ABA21 M1	0.100480-01M2	0.231410-03M3	0.800460-05
14	ABA21 M4	0.146160-04M5	0.236480-08M6	0.248660-04
14	ABA21 M7	0.159450-05M8	0.361970-04M9	0.0 D+00
14	ABA21 M10	0.127090-01M11	0.832350-02M12	0.185880-01
14	ABA22 M1	0.100500-01M2	0.229970-03M3	0.790540-05
14	ABA22 M4	0.143520-06M5	0.230730-08M6	0.249040-04
14	ABA22 M7	0.158490-05M8	0.358100-04M9	0.0 D+00
14	ABA22 M10	0.127090-01M11	0.832350-02M12	0.185880-01
14	ABA23 M1	0.100550-01M2	0.226160-03M3	0.764460-05
14	ABA23 M4	0.136660-06M5	0.215960-08M6	0.250000-04
14	ABA23 M7	0.155950-07M8	0.347940-04M9	0.0 D+00
14	ABA23 M10	0.127090-01M11	0.832350-02M12	0.185880-01
14	ABA24 M1	0.100630-01M2	0.219720-03M3	0.721260-05
14	ABA24 M4	0.125520-06M5	0.192530-08M6	0.251750-04
14	ABA24 M7	0.151620-05M8	0.331140-04M9	0.0 D+00
14	ABA24 M10	0.127090-01M11	0.832350-02M12	0.185880-01
14	ABA25 M1	0.100750-01M2	0.210420-03M3	0.660650-05
14	ABA25 M4	0.110380-06M5	0.161840-08M6	0.254230-04
14	ABA25 M7	0.145300-05M8	0.307220-04M9	0.0 D+00
14	ABA25 M10	0.127090-01M11	0.832350-02M12	0.185880-01

14	ABA26 M1	0.10092D-01M2	0.19761D-03M3	0.58022D-05
14	ABA26 M4	0.91199D-07M5	0.12505D-08M6	0.25767D-04
14	ABA26 M7	0.13642D-05M8	0.27718D-04M9	0.0 D+00
14	ABA26 M10	0.12709D-01M11	0.88325D-02M12	0.18588D-01
14	ABA27 M1	0.10110D-01M2	0.17799D-03M3	0.46377D-05
14	ABA27 M4	0.65447D-07M5	0.79833D-09M6	0.26305D-04
14	ABA27 M7	0.12227D-05M8	0.23437D-04M9	0.0 D+00
14	ABA27 M10	0.12709D-01M11	0.83235D-02M12	0.18588D-01
14	ABB21 M1	0.10147D-01M2	0.15308D-03M3	0.32857D-07
14	ABB21 M4	0.39066D-07M5	0.39687D-09M6	0.27016D-04
14	ABB21 M7	0.10318D-05M8	0.18522D-04M9	0.0 D+00
14	ABB21 M10	0.12709D-01M11	0.83235D-02M12	0.18588D-01
14	ABB22 M1	0.10179D-01M2	0.12611D-03M3	0.20809D-05
14	ABB22 M4	0.19634D-07M5	0.15645D-09M6	0.27788D-04
14	ABB22 M7	0.82348D-06M8	0.13866D-04M9	0.92000D-03
14	ABB22 M10	0.12709D-01M11	0.83235D-02M12	0.18588D-01
14	ABC21 M1	0.10157D-01M2	0.14457D-03M3	0.30532D-05
14	ABC21 M4	0.35902D-07M5	0.36427D-09M6	0.27247D-04
14	ABC21 M7	0.97448D-06M8	0.17088D-04M9	0.0 D+00
14	ABC21 M10	0.12709D-01M11	0.83235D-02M12	0.18588D-01
14	RB13 M1	0.11876D-01M2	0.10039D-03M3	0.12789D-05
14	RB13 M4	0.91239D-08M5	0.54764D-10M6	0.33406D-04
14	RB13 M7	0.69470D-06M8	0.80771D-05M9	0.0 D+00
14	RB13 M10	0.23619D-01M11	0.38902D-02M12	0.21713D-01
14	RB23 M1	0.11913D-01M2	0.67538D-04M3	0.61953D-06
14	RB23 M4	0.31349D-08M5	0.13221D-10M6	0.34244D-04
14	RB23 M7	0.48793D-06M8	0.40146D-05M9	0.0 D+00
14	RB23 M10	0.23619D-01M11	0.38902D-02M12	0.21713D-01
14	ABA31 M1	0.10162D-01M2	0.14195D-03M3	0.33283D-05
14	ABA31 M4	0.40587D-07M5	0.42059D-09M6	0.27091D-04
14	ABA31 M7	0.10675D-05M8	0.14357D-04M9	0.0 D+00
14	ABA31 M10	0.12709D-01M11	0.83235D-02M12	0.18588D-01
14	ABA32 M1	0.10163D-01M2	0.14097D-03M3	0.32831D-05
14	ABA32 M4	0.39780D-07M5	0.40939D-09M6	0.27118D-04
14	ABA32 M7	0.10603D-05M8	0.14195D-04M9	0.0 D+00
14	ABA32 M10	0.12709D-01M11	0.83235D-02M12	0.18588D-01
14	ABA33 M1	0.10166D-01M2	0.13835D-03M3	0.31641D-05
14	ABA33 M4	0.37683D-07M5	0.38070D-09M6	0.27190D-04
14	ABA33 M7	0.10413D-05M8	0.13770D-04M9	0.0 D+00
14	ABA33 M10	0.12709D-01M11	0.83235D-02M12	0.18588D-01
14	ABA34 M1	0.10172D-01M2	0.13392D-03M3	0.29665D-05
14	ABA34 M4	0.34279D-07M5	0.33530D-09M6	0.27312D-04
14	ABA34 M7	0.10087D-05M8	0.13062D-04M9	0.0 D+00

14	ABA34	M10	0.12709D-01M11	0.83235D-02M12	0.18588D-01
14	ABA35	M1	0.10179D-01M2	0.12750D-03M3	0.26896D-05
14	ABA35	M4	0.29873D-07M5	0.27627D-09M6	0.27491D-04
14	ABA35	M7	0.96108D-06M8	0.12069D-04M9	0.0 D+00
14	ABA35	M10	0.12709D-01M11	0.83235D-02M12	0.18588D-01
14	ABA36	M1	0.10190D-01M2	0.11866D-03M3	0.23253D-05
14	ABA36	M4	0.23929D-07M5	0.20695D-09M6	0.27739D-04
14	ABA36	M7	0.89431D-06M8	0.10762D-04M9	0.0 D+00
14	ABA36	M10	0.12709D-01M11	0.83235D-02M12	0.18588D-01
14	ABA37	M1	0.10205D-01M2	0.10533D-03M3	0.18125D-05
14	ABA37	M4	0.16506D-07M5	0.12555D-09M6	0.28122D-04
14	ABA37	M7	0.78990D-06M8	0.89278D-05M9	0.0 D+00
14	ABA37	M10	0.12709D-01M11	0.83235D-02M12	0.18588D-01
14	ABB31	M1	0.10224D-01M2	0.88773D-04M3	0.12373D-05
14	ABB31	M4	0.92728D-08M5	0.57654D-10M6	0.28620D-04
14	ABB31	M7	0.65134D-06M8	0.68708D-05M9	0.0 D+00
14	ABB31	M10	0.12709D-01M11	0.83235D-02M12	0.18588D-01
14	ABB32	M1	0.10243D-01M2	0.71458D-04M3	0.74392D-06
14	ABB32	M4	0.42755D-08M5	0.20271D-10M6	0.29148D-04
14	ABB32	M7	0.50279D-06M8	0.50228D-05M9	0.92000D-03
14	ABB32	M10	0.12709D-01M11	0.83235D-02M12	0.18588D-01
14	ABC31	M1	0.10230D-01M2	0.83146D-04M3	0.11259D-05
14	ABC31	M4	0.82503D-08M5	0.50677D-10M6	0.28778D-04
14	ABC31	M7	0.60958D-06M8	0.62629D-05M9	0.0 D+00
14	ABC31	M10	0.12709D-01M11	0.83235D-02M12	0.18588D-01
14	RB14	M1	0.11925D-01M2	0.56321D-04M3	0.45356D-06
14	RB14	M4	0.19871D-08M5	0.71746D-11M6	0.34502D-04
14	RB14	M7	0.42414D-06M8	0.31618D-05M9	0.0 D+00
14	RB14	M10	0.23619D-01M11	0.38902D-02M12	0.21713D-01
14	RB24	M1	0.11945D-01M2	0.38150D-04M3	0.22058D-06
14	RB24	M4	0.68812D-09M5	0.17597D-11M6	0.34984D-04
14	RB24	M7	0.29814D-06M8	0.17322D-05M9	0.0 D+00
14	RB24	M10	0.23619D-01M11	0.38902D-02M12	0.21713D-01
14	REFAX	M10	4.26485E-02M11	1.0952 E-02M12	
14	REFRD	M10	7.8857 E-02M11	1.65375E-03M12	
15	CZA1	CZA1			
15	CZA2	CZA2			
15	CZA3	CZA3			
15	CZA4	CZA4			
15	CZA5	CZA5			
15	CZA6	CZA6			
15	CZA7	CZA7			
15	CZB1	CZB1			

15	C282	C282
15	C2C1	C2C1
15	RB11	RB11
15	RB21	RB21
15	ABA11	ABA11
15	ABA12	ABA12
15	ABA13	ABA13
15	ABA14	ABA14
15	ABA15	ABA15
15	ABA16	ABA16
15	ABA17	ABA17
15	AB11	AB11
15	AB12	AB12
15	ABC11	ABC11
15	RB12	RB12
15	RB22	RB22
15	ABA21	ABA21
15	ABA22	ABA22
15	ABA23	ABA23
15	ABA24	ABA24
15	ABA25	ABA25
15	ABA26	ABA26
15	ABA27	ABA27
15	AB21	AB21
15	AB22	AB22
15	ABC21	ABC21
15	RB13	RB13
15	RB23	RB23
15	ABA31	ABA31
15	ABA32	ABA32
15	ABA33	ABA33
15	ABA34	ABA34
15	ABA35	ABA35
15	ABA36	ABA36
15	ABA37	ABA37
15	AB31	AB31
15	AB32	AB32
15	ABC31	ABC31
15	RB14	RB14
15	RB24	RB24
15	REFAX	REFAX
15	REFRD	REFRD

2 Output

No sample output is listed for other modules called by the path STP008.

Listed below is an example of the output produced by the module SYN2D. Not every page is shown, but at least one page of each type is given as an example of what to expect. Refer to Section II B.5 for a detailed description of the computations involved in calculating monitoring information and the various volumes and inventories described.

Before proceeding further, we should introduce a note of caution. The results yielded by SYN2D will only be as good as the trial functions used. A poor choice of trial functions can result in a bad approximation, for example, partially negative, two-dimensional flux. When negative fluxes are encountered, the resultant inventories that are calculated are no longer correct and in some cases can be totally meaningless. Hence, before looking at inventories, the user should check for negative fluxes.

The first page of output, which has no output page number, indicates that the link to the module was successfully completed. This is followed by a list of all data sets that were open when this module was called. If the data sets are ARC System data sets both their names and their reference numbers are listed, otherwise, only their numbers are given. These open data sets are then closed.

Output page 1 contains user-supplied information from data set A.SYN2D. The maximum number of iterations is the limit after which the iterations monitored on page 105 will be terminated. The k-effective difference, the normed flux difference, and the k-effective limits differences are the convergence criteria applied to columns 4, 10, and 7 of the iteration monitored data, respectively. The power-normalization factor for burnup is given in watts. The POINTR allocation is the size of the container array in double words ($R \times 8$) for both main and bulk core. The current interface condition can be either 'asymmetric', indicating that at each synthesis interface the trial functions on the left are weighted by the diffusion coefficient on the left in crossing the interface, or 'symmetric', indicating that trial functions from both synthesis regions are used in crossing the interface. The final message tells whether the user-supplied real trial functions are to be used as adjoints also.

Page 2 contains information on the reactor's physical characteristics and the user-imposed mesh. It first prints the geometry type (XY, RZ, or ZR). This is followed by the mesh interval boundaries in the J-direction for the first mesh interval, followed by the mesh interval boundaries for all intervals in the I-direction. For each mesh cell thus defined, the mesh-interval-lengths, two-dimensional mesh-cell volumes,

Sample Output

*****MODULE AJC009 HAS BEEN ENTERED.*****

THE FOLLOWING DATA SETS WERE OPEN BUT HAVE BEEN RECLOSED
DATA SET NAME ISAM

XS.M.NIN	37
XS.ISQ2	35
ICR002	26
PR.02	16

SAMPLE,ADJOINT WEIGHTING, DISCONTINUOUS TRIAL FUNCTIONS

PAGE 1

MAXIMUM NUMBER OF OUTER ITERATIONS= 100

ENTER ITERATION CONVERGENCE CRITERIA

REF. DIFFERENCE 0.1000000-03

SUM OF ABSOLUTE VALUE OF FLUX DIFFERENCE 0.1000000-03

DEVIATED BY THE NORMED SUM OF THE ABSOLUTE VALUES OF THE FLUX.

REF. LIMITS DIFFERENCE 0.1000000-03

PERCENT NORMALIZATION FOR NORMUP CALCULATION 0.11495000.10

*****POINTER SPACE HAS BEEN ALLOCATED.

MAIN CORE IS 30000 AND BULK CORE IS 0

THE SPECIFIC CURRENT INTERFACE CONDITION WILL BE ASSUMED.

THE REAL & ADJOINT TRIAL FUNCTIONS WILL NOT BE IDENTICAL.

SAMPLE, ADJOINT WEIGHTING, DISCONTINUOUS TRIAL FUNCTIONS

PAGE 2

GEOMETRY DATA

TR GEOMETRY

J= 1 FROM MESH LINE 0.0 TO MESH LINE 2.532
MESH INTERVAL 2.532

MESH LINES	MESH INTERVAL NUMBER	MESH INTERVAL LENGTH	MESH INTERVAL VOLUME	REGION NUMBER	COMP NUMBER
0.0					
7.620	1	7.620	153.481	1	1
15.240	2	7.620	153.481	1	1
22.860	3	7.620	153.481	1	1
30.480	4	7.620	153.481	1	1
38.100	5	7.620	153.481	1	1
45.720	6	6.350	127.901	2	13
53.340	7	6.350	127.901	2	13
60.960	8	6.350	127.901	3	25
68.580	9	6.350	127.901	3	25
76.200	10	6.350	127.901	4	37
83.820	11	6.350	127.901	4	37
91.440	12	24.670	537.184	50	44
116.110	13	26.670	537.184	50	44

J= 2 FROM MESH LINE 2.532 TO MESH LINE 5.064

SAMPLE,ADJOINT WEIGHTING, DISCONTINUOUS TRIAL FUNCTIONS

PAGE 3

DATA FOR COMPOSITION CZAL

GROUP	DIF COEF	REMOVAL	MUF FISSION	CHI	FISSION
1	3.805330 00	6.324310-02	1.899030-02	5.881530-01	6.310130-03
2	1.754490 00	1.429470-02	5.317720-03	3.791040-01	1.807650-03
3	1.277250 00	1.041230-02	4.812130-03	3.094400-02	1.664600-03
4	9.339590-01	1.317340-02	7.810980-03	1.720150-03	2.640817-03
5	1.023020 00	2.986350-02	2.144600-02	1.746210-05	7.440390-03
6	9.707190-01	5.782190-02	5.729800-02	2.009870-06	1.987750-02

SAMPLE,ADJOINT WEIGHTING, DISCONTINUOUS TRIAL FUNCTIONS

PAGE 4

TRANSFER CROSS SECTION FOR COMPOSITION CZAL

GROUP	FROM GROUP									
1	1	0.0								
2	1	3.357270-02	2	0.0						
3	4	2.452600-03	2	1.104530-02	3	0.0				
4	1	7.418010-05	2	2.233110-05	3	5.917350-03	4	0.0		
5	1	1.723810-08	2	6.331340-08	3	5.838470-07	4	2.296340-03	5	0.0
6	2	1.731860-05	3	4.060050-05	4	7.565760-08	5	2.063970-03	6	0.0

SAMPLE ADJUST WEIGHTING. DISCONTINUOUS TRIAL FUNCTIONS
 THE LARGEST CONDITION NUMBER FOR MATRIX B FOR GROUP... 1 15 0.6100 04 IN REGION NUMBER 2
 THE LARGEST CONDITION NUMBER FOR MATRIX B FOR GROUP... 2 15 0.2540 04 IN REGION NUMBER 2
 THE LARGEST CONDITION NUMBER FOR MATRIX B FOR GROUP... 3 15 0.1990 04 IN REGION NUMBER 2
 THE LARGEST CONDITION NUMBER FOR MATRIX B FOR GROUP... 4 15 0.1910 04 IN REGION NUMBER 2
 THE LARGEST CONDITION NUMBER FOR MATRIX B FOR GROUP... 5 15 0.4470 03 IN REGION NUMBER 1
 THE LARGEST CONDITION NUMBER FOR MATRIX B FOR GROUP... 6 15 0.1130 04 IN REGION NUMBER 2
 THE FOLLOWING DATA SETS WERE OPEN BY THE SYSTEM
 DATA SET NAME DISK

SC0004 28
 SC0001 25
 SC0003 27
 SC0002 26
 LIP.WANT 23

TIME FOR EXECUTION OF SYMGEN IS 0.0772 MINUTES.

SAMPLE ADJUTANT VENTURE, DISCOUNTS TRIAL FUNCTIONS

PROBLEM ITERATION HISTORY

DATE	NO.	IN.	LATEST	KEFF	KEFF	LANDA	LANDA	LANDA	SUM OF	SUM OF	QUOTIENT OF
NO.			KEFF	DIFF	UP	DOWN	DIFF	FLX DIFF	OLD FLX	LAST TWO-ARMED	
1	0	0	1.00000000	0.00000000	7.1174560	0.00000000	7.1174560	0.00000000	1.1613420	1.5600000	4.7731000-03
2	0	0	1.00000000	0.00000000	7.0791200	0.00000000	7.0791200	0.00000000	1.2165920	1.5600000	3.3890240-03
3	0	0	1.00000000	0.00000000	7.0423100	0.00000000	7.0423100	0.00000000	1.2772960	1.5600000	9.5734600-04
4	0	0	1.00000000	0.00000000	7.0055000	0.00000000	7.0055000	0.00000000	1.3380000	1.5600000	3.8873800-04
5	0	0	1.00000000	0.00000000	6.9686900	0.00000000	6.9686900	0.00000000	1.3985920	1.5600000	3.9148640-04
6	0	0	1.00000000	0.00000000	6.9318800	0.00000000	6.9318800	0.00000000	1.4591840	1.5600000	2.7347720-04
7	0	0	1.00000000	0.00000000	6.8950700	0.00000000	6.8950700	0.00000000	1.5197760	1.5600000	2.0013470-04
8	0	0	1.00000000	0.00000000	6.8582600	0.00000000	6.8582600	0.00000000	1.5803680	1.5600000	1.5034430-04
9	0	0	1.00000000	0.00000000	6.8214500	0.00000000	6.8214500	0.00000000	1.6409600	1.5600000	1.1317690-04
10	0	0	1.00000000	0.00000000	6.7846400	0.00000000	6.7846400	0.00000000	1.7015520	1.5600000	8.9561160-05
11	0	0	1.00000000	0.00000000	6.7478300	0.00000000	6.7478300	0.00000000	1.7621440	1.5600000	7.0473900-05
12	0	0	1.00000000	0.00000000	6.7110200	0.00000000	6.7110200	0.00000000	1.8227360	1.5600000	5.5996340-05
13	0	0	1.00000000	0.00000000	6.6742100	0.00000000	6.6742100	0.00000000	1.8833280	1.5600000	4.4846330-05
14	0	0	1.00000000	0.00000000	6.6374000	0.00000000	6.6374000	0.00000000	1.9439200	1.5600000	3.6140380-05
15	0	0	1.00000000	0.00000000	6.6005900	0.00000000	6.6005900	0.00000000	2.0045120	1.5600000	2.9249250-05
16	0	0	1.00000000	0.00000000	6.5637800	0.00000000	6.5637800	0.00000000	2.0651040	1.5600000	2.3767830-05
17	0	0	1.00000000	0.00000000	6.5269700	0.00000000	6.5269700	0.00000000	2.1256960	1.5600000	1.9381060-05
18	0	0	1.00000000	0.00000000	6.4901600	0.00000000	6.4901600	0.00000000	2.1862880	1.5600000	1.5657840-05
19	0	0	1.00000000	0.00000000	6.4533500	0.00000000	6.4533500	0.00000000	2.2468800	1.5600000	1.3011450-05
20	0	0	1.00000000	0.00000000	6.4165400	0.00000000	6.4165400	0.00000000	2.3074720	1.5600000	1.0701360-05
21	0	0	1.00000000	0.00000000	6.3797300	0.00000000	6.3797300	0.00000000	2.3680640	1.5600000	8.8184750-06
22	0	0	1.00000000	0.00000000	6.3429200	0.00000000	6.3429200	0.00000000	2.4286560	1.5600000	7.2378720-06
23	0	0	1.00000000	0.00000000	6.3061100	0.00000000	6.3061100	0.00000000	2.4892480	1.5600000	6.0160390-06
24	0	0	1.00000000	0.00000000	6.2693000	0.00000000	6.2693000	0.00000000	2.5498400	1.5600000	5.0779680-06
25	0	0	1.00000000	0.00000000	6.2324900	0.00000000	6.2324900	0.00000000	2.6104320	1.5600000	4.1228240-06
26	0	0	1.00000000	0.00000000	6.1956800	0.00000000	6.1956800	0.00000000	2.6710240	1.5600000	3.4172180-06
27	0	0	1.00000000	0.00000000	6.1588700	0.00000000	6.1588700	0.00000000	2.7316160	1.5600000	2.8341780-06
28	0	0	1.00000000	0.00000000	6.1220600	0.00000000	6.1220600	0.00000000	2.7922080	1.5600000	2.3518600-06
29	0	0	1.00000000	0.00000000	6.0852500	0.00000000	6.0852500	0.00000000	2.8528000	1.5600000	1.9524600-06
30	0	0	1.00000000	0.00000000	6.0484400	0.00000000	6.0484400	0.00000000	2.9133920	1.5600000	1.6215120-06
31	0	0	1.00000000	0.00000000	6.0116300	0.00000000	6.0116300	0.00000000	2.9739840	1.5600000	1.3475550-06
32	0	0	1.00000000	0.00000000	5.9748200	0.00000000	5.9748200	0.00000000	3.0345760	1.5600000	1.1193340-06
33	0	0	1.00000000	0.00000000	5.9380100	0.00000000	5.9380100	0.00000000	3.0951680	1.5600000	9.3030430-07
34	0	0	1.00000000	0.00000000	5.9012000	0.00000000	5.9012000	0.00000000	3.1557600	1.5600000	7.7331190-07
35	0	0	1.00000000	0.00000000	5.8643900	0.00000000	5.8643900	0.00000000	3.2163520	1.5600000	6.4293860-07
36	0	0	1.00000000	0.00000000	5.8275800	0.00000000	5.8275800	0.00000000	3.2769440	1.5600000	5.3434540-07
37	0	0	1.00000000	0.00000000	5.7907700	0.00000000	5.7907700	0.00000000	3.3375360	1.5600000	4.4455410-07
38	0	0	1.00000000	0.00000000	5.7539600	0.00000000	5.7539600	0.00000000	3.3981280	1.5600000	3.6970890-07
39	0	0	1.00000000	0.00000000	5.7171500	0.00000000	5.7171500	0.00000000	3.4587200	1.5600000	3.0748390-07
40	0	0	1.00000000	0.00000000	5.6803400	0.00000000	5.6803400	0.00000000	3.5193120	1.5600000	2.5574990-07

PROBLEM ITERATION HISTORY

OUTER NO.	NO. IN.	LATEST REFF	REFF OLD	LAMDA UP	LAMDA DOWN	LAMDA DIFF	SUM OF FLX DIFF	SUM OF OLD FL	QUOTIENT OF LAST TWO NAMED
41	0	1.0048190 00	-1.9409800-05	1.0000000 00	9.9900050-01	1.0070200-03	1.5807150-03	4.7632390 01	2.1272090-07
42	0	1.0047990 00	-1.6145330-05	1.0000040 00	9.9916780-01	8.3847730-04	1.3148620-03	4.7632210 01	1.7695180-07
43	0	1.0047830 00	-1.3430340-05	1.0000050 00	9.9930720-01	6.5805220-04	1.0937590-03	4.7632060 01	1.4719650-07
44	0	1.0047700 00	-1.1172250-05	1.0000040 00	9.9942530-01	5.8108160-04	9.0986120-04	4.7631940 01	1.2244820-07
45	0	1.0047590 00	-9.2940220-06	1.0000040 00	9.9952000-01	4.8364750-04	7.3699040-04	4.7631840 01	1.0186310-07
46	0	1.0047490 00	-7.7317070-06	1.0000030 00	9.9960050-01	4.0255380-04	6.2966640-04	4.7631740 01	8.4740250-08
47	0	1.0047410 00	-6.4321280-06	1.0000030 00	9.9964750-01	3.3502220-04	5.2302850-04	4.7631680 01	7.0496810-08
48	0	1.0047350 00	-5.3510470-06	1.0000020 00	9.9972330-01	2.7880490-04	4.3578760-04	4.7631620 01	5.8648230-08
49	0	1.0047300 00	-4.4517250-06	1.0000020 00	9.9976970-01	2.3201080-04	3.6254730-04	4.7631570 01	4.8791610-08
50	0	1.0047250 00	-3.7039820-06	1.0000010 00	9.9980840-01	1.9306360-04	3.0161880-04	4.7631530 01	4.0591900-08
51	0	1.0047220 00	-3.0811930-06	1.0000010 00	9.9984060-01	1.6064950-04	2.5093180-04	4.7631490 01	3.3770450-08
52	0	1.0047180 00	-2.5634140-06	1.0000010 00	9.9986730-01	1.3367410-04	2.0876400-04	4.7631470 01	2.8095520-08
53	0	1.0047160 00	-2.1324570-06	1.0000010 00	9.9988960-01	1.1122400-04	1.7368320-04	4.7631460 01	2.3374350-08
54	0	1.0047140 00	-1.7742920-06	1.0000010 00	9.9990810-01	9.2545980-05	1.4649810-04	4.7631420 01	1.9440610-08
55	0	1.0047120 00	-1.4761510-06	1.0000010 00	9.9992360-01	7.7002100-05	1.2021760-04	4.7631410 01	1.6178940-08
56	0	1.0047110 00	-1.2281120-06	1.0000000 00	9.9993640-01	6.4068180-05	1.0001730-04	4.7631390 01	1.3460380-08
57	0	1.0047090 00	-1.0217540-06	1.0000000 00	9.9994710-01	5.3306210-05	8.3211510-05	4.7631380 01	1.1198650-08
58	0	1.0047080 00	-8.5067130-07	1.0000000 00	9.9995600-01	4.4351630-05	6.9229730-05	4.7631370 01	9.3169750-09

CONVERGED REFF = 1.0047074290 00

DATASET PR.TG HAS BEEN WRITTEN OUT ON OSAM IS
 TIME FOR EXECUTION OF SYNCAL IS 1.3798 MINUTES.

CALCULATED MIXING FUNCTIONS FOR GROUP 1

R-AXIS	Z-AXIS 1	Z-AXIS 2	Z-AXIS 3	Z-AXIS 4	Z-AXIS 5	Z-AXIS 6	Z-AXIS 7
1	1.2343430 00	1.1806840 00	1.0731750 00	9.0866030-01	6.7299180-01	-1.7106390 00	-9.2019290-01
2	-2.5593790-02	-2.4395910-02	-2.1814660-02	-1.7203610-02	-8.6702360-03	2.9658970 00	1.5901380 00
R-AXIS	Z-AXIS 8	Z-AXIS 9	Z-AXIS 10	Z-AXIS 11	Z-AXIS 12	Z-AXIS 13	
1	-4.9154090-01	-2.7157580-01	-1.5079910-01	-8.9883200-02	-1.3679150-02	-1.2398480-03	
2	8.5580580-01	6.7669420-01	2.6660180-01	1.5994500-01	2.4266000-02	2.1924450-03	

SAMPLE ADJOINT WEIGHTING, DISCONTINUOUS TRIAL FUNCTIONS

PAGE 108

108

INPUT TRIAL FUNCTIONS FOR GROUP 1 REGION 1

R-AXIS	FNT NO. 1	FNT NO. 2
1	9.148532D-04	5.011207D-03
2	9.144248D-04	4.989474D-03
3	9.135677D-04	4.945601D-03
4	9.118662D-04	4.857187D-03
5	9.085947D-04	4.747625D-03
6	9.041647D-04	4.622324D-03
7	8.984556D-04	4.471854D-03
8	8.913923D-04	4.302058D-03
9	8.830821D-04	4.111955D-03
10	8.734837D-04	3.898083D-03
11	8.626260D-04	3.675522D-03
12	8.503359D-04	3.440726D-03
13	8.371942D-04	3.189931D-03
14	8.226924D-04	2.941719D-03
15	8.070883D-04	2.690802D-03
16	7.904498D-04	2.431179D-03
17	7.731057D-04	2.185149D-03
18	7.553961D-04	1.946577D-03
19	7.367156D-04	1.694572D-03
20	7.191300D-04	1.454755D-03
21	7.068079D-04	1.231461D-03
22	7.056934D-04	1.071714D-03
23	6.971952D-04	9.754158D-04
24	6.822741D-04	8.854486D-04
25	6.619532D-04	8.006248D-04
26	6.356750D-04	7.166436D-04
27	6.072874D-04	6.425820D-04
28	5.784500D-04	5.798657D-04
29	5.492554D-04	5.269290D-04
30	5.189993D-04	4.810041D-04
31	4.834892D-04	4.361401D-04
32	4.432336D-04	3.932698D-04
33	3.979136D-04	3.519023D-04
34	3.469027D-04	3.125416D-04
35	2.891402D-04	2.714392D-04
36	2.034321D-04	2.216551D-04
37	1.369648D-04	1.757845D-04
38	9.403128D-05	1.395954D-04
39	6.340488D-05	1.100832D-04
40	4.202040D-05	8.073131D-05
41	2.423426D-05	5.632052D-05
42	1.615244D-05	3.719604D-05
43	7.839317D-06	1.800634D-05
44	3.357369D-06	7.716224D-06
45	9.222555D-07	2.118353D-06

SAMPLE ADJOINT WEIGHTING, DISCONTINUOUS TRIAL FUNCTIONS

UN-NORMALIZED FLUX WILL BE READ FROM DSRN 25

RECORD 1 OF REM WRITTEN OUT ON DATA SET REFERENCE NUMBER 16

SAMPLE ADJOINT WEIGHTING, DISCONTINUOUS TRIAL FUNCTIONS

PAGE 126

REGION	VOLUME	POWER	AVERAGE POWER
CZ01	6.9066530 03	4.1555850-03	6.0167880-07
ABA11	2.3022180 03	2.4569910-04	1.0472230-07
ABA21	2.3022180 03	1.1771870-04	5.1132730-08
ABA31	2.3022180 03	4.5706780-05	1.9853370-08
CZA2	4.1440130 04	2.4866000-02	6.0064640-07
ABA12	1.3813380 04	1.4938520-03	1.2262410-07
ABA22	1.3813380 04	7.1972750-04	5.1814090-08
ABA32	1.3813380 04	2.8988050-04	2.0985490-08
CZA3	8.2879880 04	4.9264720-02	5.9447140-07
ABA13	2.7624630 04	3.6299020-03	1.3124670-07
ABA23	2.7624630 04	1.4741350-03	5.3359220-08
ABA33	2.7624630 04	5.8292720-04	2.1100200-08
CZA4	1.2432040 05	7.2567190-02	5.8371010-07
ABA14	4.1440200 04	5.9733580-03	1.4414400-07
ABA24	4.1440200 04	2.1234380-03	5.1245850-08
ABA34	4.1440200 04	8.2535230-04	1.9916710-08
CZA5	1.4975978 05	9.3888060-02	5.6641030-07
ABA15	9.5253240 04	6.5999630-03	1.1872340-07
ABA25	9.5253240 04	2.5512470-03	4.6173710-08
ABA35	9.5253240 04	9.7787860-04	1.7649120-08
CZA6	2.0720140 05	1.1205180-01	5.4079480-07
ABA16	6.9067130 04	7.1799400-03	1.0789830-07
ABA26	6.9067130 04	2.7317230-03	3.9551700-08
ABA36	6.9067130 04	1.0519390-03	1.4941100-08
CZA7	2.8530850 05	1.4292260-01	5.0094070-07
ABA17	9.5182890 04	7.9476950-03	8.3964480-08
ABA27	9.5182890 04	2.9634410-03	3.1180390-08
ABA37	9.5182890 04	1.1052700-03	1.1621840-08
CZ01	2.1197810 05	1.1309560-01	5.4298010-07
ABA11	7.8456718 04	4.6421370-03	6.5702710-08
ABA21	7.8456718 04	1.4420870-03	2.3944870-08
ABA31	7.8456718 04	6.2496160-04	8.8430350-09
CZ02	2.4444230 05	1.1493610-01	4.4638150-07
ABA12	8.2147430 04	4.2837150-03	5.2171020-08
ABA22	8.2147430 04	1.5317450-03	1.8546300-08
ABA32	8.2147430 04	5.6153130-04	1.8354330-09
CZC1	4.5424240 05	1.5702280-01	3.4191700-07
ABC11	1.5308700 05	5.8287990-03	3.8024360-08
ABC21	1.5308800 05	2.0940030-03	1.3679970-08
ABC31	1.5308800 05	7.4459890-04	4.9947410-09
AB11	9.1319890 05	2.4040830-02	5.8122390-08
AB12	1.3773300 05	3.6851230-03	2.6755340
AB13	1.3773300 05	1.2663620-03	9.1798C
AB14	1.3773300 05	4.6003340-04	3.34003
AB21	4.5584830 05	7.8352170-03	1.7188310
AB22	1.5194400 05	2.1177180-03	1.5937220
AB23	1.5194400 05	7.1997270-04	4.7389320-09
AB24	1.5194400 05	2.6455710-04	1.7411170-09
AB25	9.0056878 05	8.0	0.0
AB26	4.4741130 04	8.0	0.0

TOTAL POWER = 1.6000000 00

PR.PN WRITTEN OUT ON DATA SET REFERENCE NUMBER 17

NORMALIZATION FACTOR FOR DSRN 3.7485710 81

RECORD 2 OF CIAL WRITTEN OUT ON DATA SET REFERENCE NUMBER 16

SAMPLE ADJOINT WEIGHTING, DISCONTINUOUS TRIAL FUNCTIONS

PAGE 127

PROBLEM TYPE K CALC.				REAL FLUX FOR GROUP			
R-AXIS	I-AXIS 3.810	Z-AXIS 11.430	I-AXIS 19.050	Z-AXIS 26.670	Z-AXIS 34.290	Z-AXIS 41.275	Z-AXIS 47.625
1.264	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	2.707412E-04	2.477325E-04
3.790	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	3.202165E-04	2.738133E-04
6.390	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	4.209934E-04	3.268976E-04
9.040	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	5.266800E-04	4.353058E-04
11.847	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	6.360166E-04	5.025130E-04
14.814	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	7.560166E-04	5.988287E-04
17.947	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	8.904011E-04	7.137551E-04
21.267	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	1.0407731E-03	8.402190E-04
24.864	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	1.208380E-03	9.798270E-04
28.942	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	1.394540E-03	1.137982E-03
33.294	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	1.599370E-03	1.324549E-03
37.949	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	1.822974E-03	1.538414E-03
42.823	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	2.066830E-03	1.782877E-03
47.993	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	2.331940E-03	2.058297E-03
53.459	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	2.618510E-03	2.375130E-03
59.223	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	2.926540E-03	2.734549E-03
65.294	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	3.256040E-03	3.137982E-03
71.677	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	3.608110E-03	3.586800E-03
78.399	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	3.983740E-03	4.082877E-03
85.477	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	4.382970E-03	4.628297E-03
92.919	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	4.805800E-03	5.225130E-03
100.760	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	5.252165E-03	5.875130E-03
108.900	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	5.722970E-03	6.579820E-03
117.342	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	6.226540E-03	7.339067E-03
126.084	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	6.763740E-03	8.155817E-03
135.133	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	7.336540E-03	9.034549E-03
144.495	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	7.945800E-03	9.979820E-03
154.177	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	8.592970E-03	1.100000E-02
164.289	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	9.278540E-03	1.210000E-02
174.842	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	9.993000E-03	1.330000E-02
185.847	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	1.073740E-02	1.460000E-02
197.304	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	1.152165E-02	1.600000E-02
209.223	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	1.234540E-02	1.750000E-02
221.600	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	1.320970E-02	1.910000E-02
234.456	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	1.411540E-02	2.080000E-02
247.811	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	1.506300E-02	2.270000E-02
261.677	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	1.605370E-02	2.480000E-02
276.054	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	1.708740E-02	2.710000E-02
290.942	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	1.816540E-02	2.960000E-02
306.359	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	1.928740E-02	3.230000E-02
322.313	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	2.045370E-02	3.530000E-02
338.819	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	2.166540E-02	3.860000E-02
355.884	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	2.292370E-02	4.220000E-02
373.519	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	2.422970E-02	4.610000E-02
391.734	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	2.558370E-02	5.020000E-02
410.542	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	2.698540E-02	5.460000E-02
429.959	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	2.843740E-02	5.930000E-02
450.000	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	2.994000E-02	6.430000E-02
470.677	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	3.149370E-02	6.960000E-02
491.995	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	3.309740E-02	7.530000E-02
513.954	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	3.475165E-02	8.140000E-02
536.569	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	3.645740E-02	8.790000E-02
560.842	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	3.821540E-02	9.480000E-02
585.784	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	4.002740E-02	1.020000E-01
611.409	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	4.189370E-02	1.100000E-01
637.734	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	4.381540E-02	1.190000E-01
664.777	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	4.579370E-02	1.290000E-01
692.542	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	4.782740E-02	1.400000E-01
720.959	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	4.991740E-02	1.520000E-01
750.000	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	5.206370E-02	1.650000E-01
780.677	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	5.426540E-02	1.790000E-01
812.000	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	5.652370E-02	1.940000E-01
844.054	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	5.883740E-02	2.100000E-01
876.842	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	6.120740E-02	2.270000E-01
910.877	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	6.363370E-02	2.460000E-01
946.177	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	6.611540E-02	2.670000E-01
982.742	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	6.865370E-02	2.900000E-01
1020.584	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	7.124740E-02	3.150000E-01
1060.719	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	7.389740E-02	3.420000E-01
1103.154	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	7.660370E-02	3.710000E-01
1147.309	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	7.936740E-02	4.020000E-01
1193.194	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	8.218740E-02	4.360000E-01
1240.829	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	8.506370E-02	4.730000E-01
1290.224	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	8.799740E-02	5.130000E-01
1341.399	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	9.098740E-02	5.560000E-01
1394.374	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	9.403370E-02	5.980000E-01
1449.159	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	9.713740E-02	6.430000E-01
1505.774	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	1.002970E-01	6.910000E-01
1564.249	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	1.035165E-01	7.420000E-01
1624.594	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-05	1.526556E-05	1.067937E-01	7.960000E-01
1686.829	2.670317E-05	2.558373E-05	2.327900E-05	1.987635E-0			

SAMPLE ADJOINT WEIGHTING, DISCONTINUOUS TRIAL FUNCTIONS

PAGE 128

PROBLEM TYPE K-CALC.				REAL PLX FOR GROUP		
2-AXIS	2-AXIS 53.975	2-AXIS 60.325	2-AXIS 66.675	2-AXIS 73.025	2-AXIS 89.535	2-AXIS 116.205
1.266	1.8283250-04	1.3149730-04	8.8094470-07	6.0651540-07	6.6368330-08	7.2780490-09
1.798	1.9845440-04	1.3906770-04	9.2227810-07	6.3119643-07	9.0137730-08	7.6208950-09
6.330	2.2479080-04	1.5448030-04	1.0072040-06	6.8144516-07	9.7813380-08	8.3149940-09
9.800	2.8226220-04	1.8596930-04	1.1007330-06	7.8428370-07	1.1350000-07	9.7455560-09
13.847	3.1739030-04	2.0484550-04	1.2832610-06	8.4399380-07	1.2249420-07	1.0387250-08
18.014	3.3619580-04	2.1442110-04	1.3341920-06	8.7299140-07	1.2717448-07	1.1005670-08
22.267	3.4758430-04	2.2087330-04	1.3603370-06	8.8992840-07	1.2946750-07	1.1219390-08
26.604	3.5089645-04	2.2091400-04	1.3691100-06	8.9314140-07	1.2913800-07	1.1214480-08
30.942	3.5087130-04	2.1933060-04	1.3457490-06	8.7135800-07	1.2759308-07	1.1096990-08
35.294	3.4859730-04	2.1724260-04	1.3278770-06	8.5749730-07	1.2570880-07	1.0948460-08
39.659	3.4132830-04	2.1183650-04	1.2914200-06	8.3215180-07	1.2210830-07	1.0647010-08
44.023	3.3283810-04	2.0332330-04	1.2479700-06	8.0241800-07	1.1786000-07	1.0287990-08
48.393	3.2420350-04	1.9446310-04	1.2079420-06	7.7448910-07	1.1390530-07	9.9569900-09
52.767	3.1144330-04	1.8088760-04	1.1527810-06	7.3752080-07	1.0853760-07	9.5015500-09
57.141	2.9796700-04	1.6198710-04	1.0952890-06	6.9911230-07	1.0303240-07	9.0269270-09
61.517	2.8931830-04	1.7392120-04	1.0521720-06	6.6919170-07	9.8785630-08	8.6704500-09
65.894	2.7507230-04	1.6615080-04	9.9252320-07	6.2956540-07	9.3051100-08	8.1761240-09
70.274	2.5916760-04	1.5368860-04	9.2810840-07	5.8714610-07	8.6891990-08	7.6466370-09
74.649	2.4346850-04	1.4344380-04	8.6362470-07	5.4557590-07	8.0709940-08	7.1145260-09
79.023	2.2195880-04	1.3204230-04	7.8061800-07	4.9102840-07	7.3856340-08	6.4300910-09
83.391	2.0177910-04	1.1968150-04	7.0501180-07	4.4218850-07	6.5896290-08	5.8047680-09
87.771	1.9239930-04	1.1351880-04	6.6587440-07	4.1421450-07	6.1937750-08	5.4837490-09
92.078	1.8545670-04	1.0907440-04	6.3827350-07	3.9815240-07	5.9304910-08	5.2567640-09
96.388	1.7899180-04	1.0471810-04	6.130410-07	3.8056790-07	5.6719410-08	5.0336220-09
100.751	1.7260190-04	1.0087960-04	5.8738010-07	3.6408080-07	5.4256780-08	4.8362600-09
105.143	1.6606430-04	9.6823420-07	5.7345920-07	3.5522810-07	5.3004470-08	4.7211670-09
109.746	1.6274250-04	9.5009490-07	5.4987270-07	3.3988150-07	5.0855820-08	4.5274810-09
113.288	1.5433240-04	8.9396780-07	5.1476600-07	3.1988050-07	4.7755520-08	4.2539430-09
117.811	1.4230970-04	8.2498100-07	4.7663030-07	2.9618710-07	4.4038910-08	3.9216590-09
122.458	1.2717430-04	7.3484320-07	4.2602720-07	2.6309940-07	3.9775810-08	3.5078160-09
127.229	1.1346890-04	6.3784740-07	3.8059760-07	2.3511400-07	3.5118600-08	3.1326800-09
132.088	1.0250930-04	5.9426370-07	3.3774540-07	2.1236370-07	3.1775470-08	2.8297180-09
136.771	9.4638120-07	5.4343000-07	3.1478860-07	1.9434750-07	2.9088680-08	2.5912840-09
141.942	8.6811750-07	5.0867380-07	2.9318130-07	1.8099180-07	2.7101830-08	2.4160040-09
147.313	8.4617690-07	4.8748500-07	2.8046000-07	1.7249950-07	2.5844500-08	2.3083920-09
152.954	9.2133440-07	5.2631250-07	3.0077170-07	1.8390510-07	2.7651230-08	2.4750640-09
158.665	9.4046518-07	5.3425380-07	3.0369450-07	1.8505650-07	2.7877620-08	2.5003280-09
164.976	8.6698220-07	5.0277690-07	2.8495260-07	1.7313350-07	2.6109930-08	2.3443740-09
171.287	7.9833230-07	4.5119450-07	2.5552830-07	1.5501970-07	2.3394690-08	2.1021830-09
177.153	6.8189220-07	3.8468010-07	2.1743440-07	1.3170780-07	1.9890990-08	1.7886970-09
183.574	5.3627320-07	2.9647320-07	1.6744850-07	1.0133340-07	1.5310270-08	1.3773860-09
189.995	3.1238940-07	2.0952120-07	1.1823410-07	7.1524570-08	1.0809490-08	9.7275310-10
197.485	2.6888140-07	1.4626840-07	8.2732890-08	6.3671330-08	7.5152700-09	6.7714780-10
204.803	1.3458840-07	8.6558840-08	4.8634000-08	3.8297920-08	4.4362250-09	4.0000420-10
211.281	5.8138940-08	2.8053370-08	1.5750830-08	9.4824150-09	1.4362630-09	1.2954500-10

POWER NORMALIZATION
PLX NORMALIZATION FACTOR = 3.7485710 01

GROUP 3 OF REAL WRITTEN OUT ON DATA SET REFERENCE NUMBER 18

111

112

SAMPLE, ADJUNCT WEIGHTING, DISCONTINUOUS TRIAL FUNCTIONS

PAGE 139

POWER PER INTERVAL

R-AXIS	Z-AXIS 3.810	I-AXIS 11.430	I-AXIS 19.050	I-AXIS 26.670	Z-AXIS 34.290	Z-AXIS 41.275	Z-AXIS 47.625
1.246	7.1419260-07	5.8439680-07	6.2634000-07	5.4332730-07	4.4099350-07	1.1249960-07	9.2045810-08
3.798	7.1409230-07	6.8430110-07	6.2622200-07	5.4325020-07	4.4092200-07	1.1539310-07	9.3566430-08
6.330	7.1389120-07	6.9410870-07	6.2608630-07	5.4309440-07	4.4077730-07	1.2126620-07	9.6651030-08
9.680	7.1363900-07	6.9534000-07	6.2586260-07	5.4289370-07	4.4057790-07	1.3271540-07	1.0252460-07
13.047	7.1251627-07	6.8279630-07	6.2489510-07	5.4206530-07	4.3989270-07	1.3987860-07	1.0601250-07
16.016	7.1089440-07	6.8119440-07	6.2344500-07	5.4082950-07	4.3889260-07	1.4289220-07	1.0739320-07
22.267	7.0893250-07	6.7937940-07	6.2180550-07	5.3943900-07	4.3777630-07	1.4797480-07	1.0997990-07
26.484	7.0591700-07	6.7650160-07	6.1919830-07	5.3721770-07	4.3599480-07	1.5143280-07	1.1169980-07
30.942	7.0221310-07	6.7294570-07	6.1599240-07	5.3448260-07	4.3380070-07	1.5299170-07	1.1227130-07
35.294	6.9838360-07	6.6931080-07	6.1268080-07	5.3166070-07	4.3153900-07	1.6821090-07	1.2377230-07
39.659	6.9308210-07	6.6424420-07	6.0808110-07	5.2772530-07	4.2837790-07	1.6881230-07	1.2234900-07
44.023	6.8891700-07	6.5835460-07	6.0272560-07	5.2333590-07	4.2468700-07	1.6434440-07	1.2019460-07
48.393	6.8043220-07	6.5234870-07	5.9726660-07	5.1845780-07	4.2092360-07	1.4233200-07	1.0254130-07
52.747	6.7249390-07	6.4455820-07	5.9017270-07	5.1235910-07	4.1600550-07	1.3856170-07	9.9575640-08
57.141	6.6326260-07	6.3573460-07	5.8213070-07	5.0543340-07	4.1040940-07	1.3428170-07	9.6247080-08
61.517	6.5372690-07	6.2661060-07	5.7381100-07	4.9826090-07	4.0460240-07	1.2671240-07	9.0134510-08
65.894	6.4410190-07	6.1548140-07	5.6365050-07	4.8947970-07	3.9746790-07	1.2196920-07	8.6515690-08
70.274	6.3491410-07	6.0307000-07	5.5230800-07	4.7965570-07	3.8945300-07	1.1666070-07	8.2568100-08
74.644	6.2412950-07	5.8868940-07	5.3915340-07	4.6823560-07	3.8008690-07	1.0450000-07	7.4087610-08
79.020	6.1356550-07	5.7089320-07	5.2284400-07	4.5401780-07	3.6833080-07	9.8417620-08	6.9063600-08
84.391	6.0244930-07	5.5082750-07	5.0441720-07	4.3787350-07	3.5482720-07	9.1621420-08	6.4204570-08
88.577	6.7298020-07	6.4509980-07	5.9081120-07	5.1307290-07	4.1634360-07	8.1570720-08	5.6523450-08
90.978	6.5591530-07	6.2872460-07	5.7676440-07	4.9988140-07	4.0532380-07	7.9008350-08	5.4649840-08
93.380	6.3608040-07	6.0949690-07	5.5829850-07	4.8481640-07	3.9269240-07	7.6462740-08	5.2792450-08
95.781	6.1744150-07	5.8795390-07	5.3834970-07	4.6720800-07	3.7836130-07	7.4109610-08	5.1097410-08
98.243	5.9446870-07	5.6497830-07	5.2167790-07	4.5266490-07	3.6641520-07	6.6619170-08	4.9257150-08
100.76	5.6685910-07	5.4040910-07	4.9751130-07	4.3164960-07	3.4928730-07	6.4292450-08	4.757130-08
103.288	5.4090200-07	5.1803410-07	4.7430510-07	4.1152610-07	3.3300600-07	6.1052740-08	4.559710-08
105.811	5.1498000-07	4.9360490-07	4.5195190-07	3.9219380-07	3.1747340-07	5.7125300-08	4.3750120-08
108.438	4.8817690-07	4.6601650-07	4.2674320-07	3.7042090-07	3.0003770-07	5.5519480-08	4.2085070-08
111.229	4.5742600-07	4.3867370-07	4.0176140-07	3.4885590-07	2.8280990-07	5.0615630-08	4.0833800-08
114.000	4.2446600-07	4.0882730-07	3.7448630-07	3.2530350-07	2.6398890-07	4.6363040-08	3.1963230-08
116.771	3.9322040-07	3.7698360-07	3.4538820-07	3.0018540-07	2.4394670-07	4.2702580-08	2.9437720-08
119.542	3.5837980-07	3.4361510-07	3.1490570-07	2.7389650-07	2.2303390-07	3.9614720-08	2.7243170-08
122.313	3.2244310-07	3.0920290-07	2.8348690-07	2.4684210-07	2.0161640-07	3.7130440-08	2.5393470-08
125.154	2.7422090-08	2.3842240-08	2.3848880-08	2.1218660-08	1.74218660-08	3.5193600-08	2.2909233-08
128.045	2.3748220-08	2.2615460-08	2.2619590-08	1.7650850-08	1.6339760-08	3.4492730-08	2.2145060-08
131.978	2.0131440-08	1.9670200-08	1.968790-08	1.5166120-08	1.4584270-08	3.2041440-08	2.0474480-08
135.287	1.6363140-08	1.6469790-08	1.6789160-08	1.35523420-08	1.28952940-08	2.8849050-08	1.8355570-08
138.133	1.2750670-08	1.26385430-08	1.24205570-08	1.1087180-08	1.17187920-08	2.2061930-08	1.3688460-08
143.574	1.0669660-08	1.0873660-08	1.1733170-08	1.5134150-08	1.2419180-08	1.7289200-08	1.0748050-08
147.995	1.4054160-08	1.3491870-08	1.2400370-08	1.0655620-08	1.0668530-09	1.2505820-08	7.8052740-09
152.405	0.0	0.0	0.0	0.0	0.0	0.0	0.0
156.803	0.0	0.0	0.0	0.0	0.0	0.0	0.0
161.201	0.0	0.0	0.0	0.0	0.0	0.0	0.0

EXAMPLE ADJOINT WEIGHTING, DISCONTINUOUS TRIAL FUNCTIONS

PAGE 140

POWER PER INTERVAL

R-AXIS	Z-AXIS 52.975	Z-AXIS 60.325	Z-AXIS 66.675	Z-AXIS 73.025	Z-AXIS 84.535	Z-AXIS 116.205
1.266	5.647849D-08	4.316788D-08	2.199764D-08	1.499850D-08	0.0	0.0
3.798	7.743789D-08	4.358834D-08	2.222104D-08	1.712739D-08	0.0	0.0
6.330	5.982944D-08	4.444139D-08	2.267472D-08	1.788913D-08	0.0	0.0
9.440	3.818722D-08	4.301891D-08	2.358647D-08	1.784922D-08	0.0	0.0
13.847	5.994229D-08	4.390686D-08	2.397303D-08	1.809463D-08	0.0	0.0
18.814	4.060288D-08	4.418450D-08	2.409650D-08	1.812927D-08	0.0	0.0
23.767	6.133081D-08	4.452421D-08	2.418820D-08	1.810423D-08	0.0	0.0
28.604	6.228992D-08	4.479386D-08	2.423988D-08	1.808586D-08	0.0	0.0
33.942	6.225945D-08	4.467305D-08	2.409302D-08	1.793404D-08	0.0	0.0
39.294	6.092145D-08	4.352301D-08	2.341749D-08	1.737447D-08	0.0	0.0
44.659	6.003274D-08	4.278923D-08	2.293948D-08	1.700893D-08	0.0	0.0
49.823	5.880316D-08	4.182490D-08	2.238319D-08	1.636004D-08	0.0	0.0
54.999	5.802967D-08	3.968884D-08	2.120289D-08	1.543793D-08	0.0	0.0
60.167	5.426307D-08	3.836951D-08	2.044650D-08	1.504995D-08	0.0	0.0
65.317	5.230909D-08	3.692020D-08	1.962473D-08	1.444263D-08	0.0	0.0
70.474	4.874937D-08	3.422097D-08	1.814401D-08	1.331147D-08	0.0	0.0
75.649	4.666263D-08	3.269129D-08	1.730638D-08	1.266826D-08	0.0	0.0
80.821	4.441356D-08	3.106786D-08	1.640333D-08	1.199748D-08	0.0	0.0
85.994	1.863911D-08	2.756540D-08	1.455493D-08	1.059721D-08	0.0	0.0
91.167	1.669814D-08	2.541015D-08	1.348115D-08	9.816298D-09	0.0	0.0
96.330	1.416098D-08	2.371647D-08	1.244632D-08	9.041776D-09	0.0	0.0
101.493	2.994737D-08	2.042511D-08	1.087485D-08	7.669260D-09	0.0	0.0
106.656	2.899362D-08	1.988139D-08	1.046791D-08	7.571126D-09	0.0	0.0
111.819	2.794296D-08	1.915487D-08	1.007144D-08	7.282004D-09	0.0	0.0
116.982	2.692900D-08	1.847326D-08	9.700453D-09	7.011378D-09	0.0	0.0
122.145	2.589530D-08	1.762214D-08	9.383597D-09	6.158221D-09	0.0	0.0
127.308	2.296830D-08	1.557049D-08	8.229391D-09	5.900036D-09	0.0	0.0
132.471	2.178061D-08	1.476630D-08	7.792444D-09	5.586988D-09	0.0	0.0
137.634	2.019120D-08	1.388038D-08	7.293808D-09	5.232448D-09	0.0	0.0
142.797	1.998174D-08	1.365672D-08	7.136070D-09	5.150223D-09	0.0	0.0
147.960	1.824950D-08	1.281440D-08	6.338200D-09	4.720549D-09	0.0	0.0
153.123	1.675785D-08	1.169216D-08	5.994614D-09	4.334909D-09	0.0	0.0
158.286	1.542798D-08	1.087988D-08	5.814000D-09	1.988613D-09	0.0	0.0
163.449	1.437192D-08	9.772288D-09	5.096126D-09	1.479184D-09	0.0	0.0
168.612	1.359690D-08	9.872198D-09	4.730418D-09	8.407267D-09	0.0	0.0
173.775	1.218841D-08	8.341387D-09	4.375872D-09	3.870903D-09	0.0	0.0
178.938	1.176548D-08	7.677487D-09	4.173404D-09	2.905138D-09	0.0	0.0
184.101	1.084018D-08	7.092649D-09	3.829290D-09	2.653274D-09	0.0	0.0
189.264	9.722958D-09	6.308165D-09	3.616617D-09	2.364933D-09	0.0	0.0
194.427	7.418412D-09	4.323630D-09	2.644508D-09	1.810841D-09	0.0	0.0
199.590	5.817065D-09	3.710927D-09	2.876986D-09	1.422789D-09	0.0	0.0
204.753	4.221788D-09	2.701642D-09	1.811051D-09	1.037940D-09	0.0	0.0
209.916	0.0	0.0	0.0	0.0	0.0	0.0
215.079	0.0	0.0	0.0	0.0	0.0	0.0
220.242	0.0	0.0	0.0	0.0	0.0	0.0

MAXIMUM POWER= 8.71419D-08 OCCURS AT POINT 3.810 1.266

MINIMUM POWER= 8.10373D-08 OCCURS AT POINT 73.025 147.993

POWER NORMALIZATION
FLUX NORMALIZATION FACTOR = 3.748971D-01

114

FLUX VOLUME						
REGION	GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP 5	GROUP 6
CAA1	7.5287430-04	6.1974540-01	6.6405170-01	2.9448280-01	2.2849620-02	8.5776670-04
CAA11	7.7244410-03	6.8301720-02	1.30493720-01	6.7287480-02	7.3777360-03	4.9557170-04
CAA21	4.1134640-03	3.4776030-02	7.2448080-02	4.4473030-02	4.9967860-03	3.3708370-04
CAA31	1.8461840-03	1.8125880-02	2.9437040-02	2.8374600-02	4.4761110-03	5.7979080-04
CIA2	9.1526740-01	3.7032830-00	3.7032830-00	1.7619760-00	1.3636240-01	1.1203280-03
CAA12	6.7101830-02	4.0254330-01	7.8817300-01	4.0059190-01	4.3481250-02	2.8937050-03
AA622	1.6035410-02	2.1362710-01	4.7633490-01	2.6742160-01	1.5052990-02	3.1172540-03
AA622	1.6035410-02	1.0594090-01	2.1370910-01	1.8854410-01	2.6326880-02	3.4012950-03
CIA1	1.6108930-00	7.3258840-00	7.8895460-00	3.6203820-00	2.7049820-01	1.0118910-02
AA623	2.0331870-01	1.0046750-00	1.3726720-00	7.8803120-01	8.3956130-02	5.5225000-03
AA621	7.4497220-02	6.0430260-01	6.7841590-01	5.2366980-01	4.1358920-02	5.9716600-03
AA623	1.0839410-02	2.3772760-01	4.7640570-01	3.2901160-01	5.0427570-02	6.4419300-03
CIA4	2.6588540-00	1.0755380-01	1.1651450-01	5.1396500-00	3.2834380-01	1.4854450-02
AA614	3.0636678-01	1.4620570-00	2.2925910-00	1.1340980-00	1.1847420-01	7.6759310-03
AA624	1.1418800-01	4.0093890-01	1.9059940-00	7.5025680-01	9.4252870-02	8.2072640-03
AA624	4.3819390-02	3.6700790-01	6.34630-01	4.6932510-01	7.0207030-02	5.8220210-03
CIA5	3.4904940-00	1.3870810-01	1.5172590-01	6.6399810-00	5.1438820-01	1.9111640-02
AA615	1.8323010-01	2.1674180-00	2.8468140-00	1.4072910-00	1.4352470-01	9.1571480-03
AA625	1.3934180-01	1.0178000-00	1.6131700-00	9.2298660-01	1.1307420-01	9.6577350-03
AA625	5.2044390-02	4.5758620-01	8.6888630-01	5.7459600-01	8.3732000-02	1.0335340-02
CIA6	4.0424230-00	1.6542030-01	1.1100490-01	7.8741930-00	6.0771670-01	2.2459840-02
AA616	4.3521360-01	2.5023480-00	3.1641440-00	1.5770300-00	1.5741190-01	9.9101430-03
AA626	1.5164900-01	1.1482070-00	1.8209320-00	1.0268680-00	1.2265790-01	1.0268560-02
AA626	5.5772460-02	5.0712040-01	9.7580210-01	6.3599780-01	9.0216780-02	1.0925140-02
CIA7	5.3429160-00	2.1286580-01	2.3040620-01	9.7588940-00	7.2308920-01	2.6343000-02
AA617	4.9790100-01	2.9676170-00	3.7140690-00	1.4897540-00	1.8653610-01	1.1660810-02
AA627	1.6881790-01	1.3323790-00	2.1446530-00	1.2144960-00	1.4273390-01	1.1577450-02
AA627	6.0403060-02	5.7831040-01	1.1430150-00	7.4734170-01	1.0318920-01	1.2188620-02
CIA8	2.8322760-00	1.14505510-01	1.5188630-01	6.0382600-00	4.0162810-01	1.2277190-02
AA611	3.1453270-01	1.8598680-00	2.2945280-00	1.2023320-00	1.2350450-01	7.9831110-03
AA622	1.0208290-01	6.2032290-01	1.3317770-00	7.6971410-01	9.2216600-02	7.2740630-03
AA621	3.5831820-02	3.9083090-01	7.0856830-01	4.7088700-01	6.6089100-02	7.3853430-03
CIA9	3.8639410-00	1.4607650-01	1.5120410-01	5.6728710-00	3.1541240-01	7.3180940-03
AA612	3.2107920-01	1.8731080-00	2.2297610-00	1.2190150-00	1.3432710-01	9.0976840-03
AA622	1.0210070-01	7.4413600-01	1.3004740-00	7.7512830-01	9.7899960-02	7.4912290-03
AA622	3.5105730-02	3.1603940-01	6.9030050-01	4.7162570-01	6.8920240-02	7.2838570-03
CIA1	5.0051240-00	1.9303990-01	2.0974940-01	8.4324630-00	5.8860370-01	2.8457660-02
AA611	3.8542040-01	2.2457330-00	2.9893190-00	1.4343700-00	1.6711980-01	1.0713580-02
AA621	1.2209700-01	1.0150750-00	1.7502020-00	1.0384010-00	1.2243880-01	9.2117840-03
AA621	6.1811820-02	4.7949180-01	9.2729830-01	6.2951870-01	8.6506780-02	9.2728740-03
AA611	1.1428320-00	7.9715240-00	1.0920890-01	5.0465250-00	5.2409330-01	3.8304460-02
AA622	3.1457520-01	1.4008340-00	1.7176890-00	9.6618410-01	9.3294020-02	5.1942660-03
AA612	9.5594170-02	5.9797110-01	1.0101150-00	6.0950200-01	6.8820970-02	4.9321600-03
AA614	1.1661970-02	2.4858460-01	5.3405490-01	3.4880240-01	4.8017980-02	5.0144710-03
AA621	3.2094990-01	3.0671580-00	5.4201120-00	2.9211790-00	3.8057700-01	6.0755380-02
AA622	2.0780480-01	9.2752840-01	1.0934290-00	6.1186690-01	5.7201530-02	2.9479110-03
AA623	4.2197940-02	3.9130610-01	6.4857110-01	3.8472760-01	4.1632600-02	2.8526940-03
AA624	2.0330160-02	1.4095080-01	3.4664910-01	2.3221770-01	2.9281070-02	2.9635230-03
REFR0	1.4384930-01	1.5046190-00	2.4036170-00	1.4333370-00	2.1698090-01	3.7591380-02
REFAX	1.1276120-01	2.4097120-00	7.5216100-00	7.4651520-00	1.8248700-00	6.4337870-04

SAMPLE ADJACENT WEIGHTING, DISCONTINUOUS TRIAL FUNCTIONS

PAGE 142

REGION		GROUP		GROUP		GROUP		GROUP		GROUP		GROUP	
REGION		GROUP		GROUP		GROUP		GROUP		GROUP		GROUP	
CEA1	1.0074450	14	1.1973630	15	3.4261370	13	1.5204000	15	1.1789130	14	4.4256010	12	
ABA11	1.1054500	14	1.0571070	15	2.0266900	13	1.0410840	15	1.1419510	14	7.6706260	12	
ABA21	4.3703630	13	3.6973180	14	1.1213740	15	6.9610770	14	9.2201140	13	8.3131620	12	
ABA31	2.8085620	13	2.3054270	14	6.1972940	14	4.3922260	14	5.9262740	13	8.9761940	12	
CEA2	7.8704130	14	3.1861840	15	3.4180270	13	1.3151290	15	1.1743050	14	4.8029840	12	
ABA12	7.2469730	14	1.8384500	15	2.0286190	13	1.0334110	15	1.1209140	14	7.4649170	12	
ABA22	9.3843040	13	5.8425530	14	1.1254270	15	4.8987010	14	9.8426540	13	8.1190010	12	
ABA32	3.7842640	13	7.7329660	14	4.1810400	14	4.3479480	14	6.7913710	13	8.7783530	12	
CEA3	7.7879970	14	3.1457900	15	3.3921390	13	1.5004440	15	1.1630170	14	4.3306410	12	
ABA13	2.6290820	14	1.2950900	15	2.0285280	13	1.0164500	15	1.0829170	14	7.1237550	12	
ABA23	1.0120950	14	6.3048020	14	1.1330340	15	4.7546100	14	8.6883620	13	7.7026100	12	
ABA33	3.9804340	13	3.0461550	14	6.1421320	14	4.2637910	14	4.3064450	13	8.3052190	12	
CEA4	7.4840420	14	3.0829170	15	3.3397010	13	1.4731980	15	1.1417880	14	4.2577880	12	
ABA14	2.8144700	14	1.4292080	15	1.9714010	13	7.7693300	14	1.0187620	14	8.8025640	12	
ABA24	9.8109500	13	4.8872870	14	1.1087840	15	4.4514710	14	8.1040100	13	7.0574400	12	
ABA34	1.7600170	13	3.1559070	14	5.9930010	14	4.0337360	14	6.0371140	13	7.5860730	12	
CEA5	7.3747680	14	2.5819820	15	3.2510270	13	1.4274420	15	1.1058130	14	6.1085590	12	
ABA15	2.4710770	14	1.3978340	15	1.8359970	13	9.0758860	14	9.2361430	13	5.9057180	12	
ABA25	8.9220670	13	4.3641000	14	1.0616720	15	3.9525950	14	7.2925010	13	6.2285670	12	
ABA35	7.1363610	13	2.9511000	14	5.6037120	14	3.7057450	14	5.4001320	13	6.6655140	12	
CEA6	7.8290100	14	2.8440950	15	3.1124220	13	1.3542030	15	1.0491310	14	3.8676440	12	
ABA16	2.2434410	14	1.2918620	15	9.6628270	13	8.1365270	14	8.1215080	13	5.1130400	12	
ABA26	7.8269830	13	3.9246680	14	9.2960210	14	9.2960210	14	6.3285140	13	5.2479400	12	
ABA36	2.8773230	13	1.8164570	14	5.0945340	14	3.2813420	14	4.8360950	13	5.6367190	12	
CEA7	6.6728890	14	3.6385340	15	2.8777300	13	1.7188880	15	9.1168840	13	3.2403040	12	
ABA17	1.0624870	14	1.1119790	15	1.3916410	13	7.0513770	14	6.9694040	13	4.3692400	12	
ABA27	4.2950400	13	4.4423510	14	8.0239810	14	4.8806480	14	5.3487570	13	4.3380070	12	
ABA37	2.2632590	13	2.1660970	14	4.2828120	14	3.8003230	14	3.8899230	13	4.3482770	12	
CEA8	6.4624750	14	2.4285340	15	2.1931780	13	1.0110980	15	4.7514070	13	2.8459310	12	
ABA18	1.3763040	14	9.3798250	14	1.1372040	15	8.0617730	14	6.2267370	13	4.0261430	12	
ABA28	3.1483750	14	4.1371500	14	6.7188880	14	3.8814210	14	4.6548280	13	3.8883490	12	
ABA38	1.8871140	15	1.7694970	14	3.3735430	14	2.3748380	14	3.3309000	13	5.7244710	12	
CEA9	3.3899840	14	2.1123040	15	2.1435740	13	8.7026700	14	6.5563930	13	1.0301850	12	
ABA19	1.3897000	14	7.9884070	14	4.6724510	14	3.2479320	14	3.8269390	13	3.8444880	12	
ABA29	4.4289990	13	3.4440640	14	5.4410070	14	7.3624080	14	4.2467740	13	1.2493990	12	
ABA39	6.8239410	13	1.4577830	14	8.9994390	14	2.8467190	14	2.7896720	13	3.1396440	12	
CEA10	3.8810030	14	1.4577870	15	1.4274040	13	6.8430930	14	4.5672170	13	1.5873930	12	
ABA20	8.9885440	13	5.8780540	14	8.9780540	14	1.8849880	14	1.8902330	13	2.4989310	12	
ABA30	2.8420000	13	3.4094700	14	6.3741400	14	2.4129570	14	2.8981990	13	2.1676180	12	
CEA11	9.7880000	12	1.0734120	14	2.7583670	14	1.4854080	14	7.8137250	13	2.1583140	12	
ABA21	1.5880000	14	6.8754000	14	9.4182340	14	4.3521300	14	4.8108090	13	3.3033980	12	
ABA31	8.1887000	13	3.6843610	14	4.4440030	14	2.4977270	14	2.4137180	13	1.3956130	12	
CEA12	2.4990000	13	2.4470000	14	2.4470000	14	1.3769130	14	1.3769130	13	1.2760560	12	
ABA22	5.1916000	13	6.4214700	13	1.3017130	14	9.8417140	13	1.2433290	13	1.2975520	12	
ABA32	2.8790000	13	2.3850000	14	4.2371600	14	2.2839790	14	2.9790930	13	1.1459740	12	
CEA13	4.8734700	13	2.1732340	14	2.3843000	14	1.4344920	14	1.9414080	13	4.0134300	12	
ABA23	1.4580000	12	9.1760000	12	1.3129900	14	9.8226100	13	4.7634620	12	6.8801280	12	
ABA33	4.7490000	12	3.7744110	13	7.9050000	13	3.4439610	13	4.8849050	12	6.9800470	12	
CEA14	5.1470000	12	4.6780000	13	3.8440000	13	3.8440000	13	7.8028220	12	1.3322060	12	
ABA24	8.9807700	11	2.2174210	13	5.9906000	13	5.9906000	13	1.4334350	13	5.1242310	12	

LEAKAGE						
REGION	GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP 5	GROUP 6
C241	9.748200D-04	1.450054D-03	1.351609D-04	7.124740D-05	-7.208147D-06	-1.864424D-06
ABA11	-1.483776D-03	-1.140408D-03	3.058790D-04	9.155160D-03	7.491457D-05	2.088376D-06
ABA21	-2.580800D-04	+1.629262D-04	-1.930815D-04	-7.468234D-05	-3.007221D-06	3.986527D-07
ABA31	-9.322200D-05	-1.025701D-04	-1.384733D-04	-4.809006D-05	-5.994138D-06	-2.167540D-06
C242	3.719848D-03	6.986743D-03	1.006457D-03	6.354310D-04	-3.191873D-05	-1.867565D-05
ABA12	-2.759680D-03	-4.394750D-03	1.000535D-03	6.873845D-04	1.260890D-04	1.009977D-05
ABA22	-3.879690D-04	-2.013590D-03	-1.132980D-03	-1.765625D-04	1.157528D-05	1.061367D-06
ABA32	-1.854934D-04	-1.032032D-03	-7.924517D-04	-3.031740D-04	-4.150491D-05	-1.299548D-05
C243	5.975634D-03	1.276007D-02	2.319441D-03	9.618762D-04	-7.762740D-05	-1.948879D-05
ABA13	-2.990112D-03	-4.452276D-03	1.760736D-03	1.001453D-03	2.351440D-04	1.908955D-05
ABA23	-1.202394D-03	-1.631907D-03	-1.954927D-03	-3.108791D-04	2.376259D-05	3.101352D-06
ABA33	-4.876474D-04	-1.127967D-03	-1.457757D-03	-5.757412D-04	-7.943574D-05	-2.462695D-05
C244	6.356061D-03	1.416672D-02	4.912371D-03	1.797864D-03	-5.113157D-05	-2.505745D-05
ABA14	-3.885240D-03	-1.519051D-03	4.902403D-03	1.262982D-03	2.075914D-04	2.544055D-05
ABA24	-1.425313D-03	-3.495762D-03	-2.340501D-03	-4.233394D-04	3.132214D-05	3.784773D-06
ABA34	-7.432994D-04	-2.164899D-03	-2.074432D-03	-8.189547D-04	-1.154914D-04	-3.521117D-05
C245	1.116478D-02	1.723450D-02	1.000941D-02	3.780440D-03	4.454240D-05	-2.570497D-05
ABA15	-5.035722D-03	-1.189093D-03	2.816022D-03	9.810312D-04	2.834603D-04	2.847220D-06
ABA25	-2.585387D-03	-9.525151D-04	-3.109537D-03	-5.344228D-04	3.119544D-05	1.406882D-06
ABA35	-4.455758D-04	-3.034913D-03	-2.454183D-03	-1.018715D-03	-1.557079D-04	-4.330304D-05
C246	1.343768D-02	2.175849D-02	1.812275D-02	5.479131D-03	1.089146D-04	-1.888370D-05
ABA16	-6.953071D-03	-2.417890D-03	-2.239163D-03	-2.966020D-04	1.307015D-04	2.574207D-05
ABA26	-2.864621D-03	-6.564497D-03	-3.353417D-03	-7.905012D-04	-4.629467D-06	1.406611D-06
ABA36	-3.025828D-03	-3.500125D-03	-3.033730D-03	-1.249634D-03	-1.864095D-04	-4.919878D-05
C247	1.354894D-02	3.374033D-02	3.350599D-02	1.149166D-02	1.119786D-03	1.989777D-05
ABA17	-1.321381D-03	-9.993537D-03	-1.104761D-02	-1.069113D-03	1.864179D-04	3.426362D-05
ABA27	-3.464910D-03	-8.593175D-03	-3.999130D-03	-9.303595D-04	-3.270987D-05	-2.366057D-06
ABA37	-1.266844D-03	-4.422987D-03	-1.725745D-03	-1.501834D-03	-2.490567D-06	-4.249391D-05
C248	3.427576D-02	4.712724D-02	2.747740D-02	4.389439D-03	3.993444D-04	-2.476755D-05
ABA18	-1.221540D-02	-1.108182D-02	-1.172007D-02	-5.378845D-04	2.332502D-04	1.619476D-06
ABA28	-2.578171D-03	-3.676007D-03	-2.541819D-03	-4.094971D-04	-1.342184D-04	-1.051001D-05
ABA38	-8.494539D-04	-2.854817D-03	-2.454440D-03	-1.146097D-03	-2.365623D-04	-1.052433D-05
C249	1.827825D-02	3.947630D-02	2.870257D-02	-6.417636D-03	-3.160113D-03	-2.735014D-06
ABA19	-7.558791D-03	-9.662400D-03	-1.160940D-02	-2.386490D-03	1.264010D-03	1.289325D-06
ABA29	-1.802544D-03	-4.642510D-03	-1.190862D-03	7.461396D-05	2.581440D-04	1.344740D-05
ABA39	-5.003199D-04	-2.446253D-03	-2.076580D-03	-5.434822D-04	1.029468D-05	-4.451055D-05
C250	5.454329D-03	3.728179D-02	3.444788D-02	7.849144D-03	-7.821864D-04	-1.945716D-06
ABA20	-2.131101D-02	-1.922045D-02	-2.164762D-02	-1.435520D-03	2.142790D-04	4.686476D-05
ABA40	-4.486262D-03	-8.808837D-03	-4.101342D-03	-1.463830D-03	-7.216751D-06	-1.632647D-05
ABA41	-1.443273D-03	-4.261765D-03	-3.758224D-03	-1.810837D-03	-1.492644D-04	-7.144289D-05
ABA42	-4.742331D-02	-3.662235D-02	3.039347D-03	3.328420D-03	1.950493D-03	2.523360D-06
ABA43	-4.181217D-03	-6.109649D-03	-6.391335D-03	-3.783267D-04	-2.803531D-04	-6.443456D-06
ABA44	-9.327190D-04	-3.995171D-03	-1.816430D-02	-4.814930D-04	-4.291807D-05	-5.194980D-06
ABA45	-2.492724D-04	-1.787254D-03	-1.508009D-03	-6.129475D-04	-1.151164D-04	-3.249712D-06
ABA46	-1.323436D-02	-3.056854D-02	-1.378440D-02	-3.416508D-03	-8.371491D-05	-3.634965D-06
ABA47	6.494678D-03	1.215922D-02	4.995340D-04	7.718790D-03	1.284561D-04	-6.623849D-06
ABA48	-1.421940D-02	-2.193051D-03	-4.724620D-04	-4.894232D-04	-4.109101D-05	-2.854111D-06
ABA49	-4.144550D-04	-9.440190D-04	-8.643678D-04	-4.981897D-04	-8.179628D-05	-1.001782D-05
ABA50	-2.426223D-03	-4.161555D-03	-3.309294D-03	-1.015640D-03	1.998890D-04	2.0929417D-06
ABA51	-3.658771D-03	-1.542715D-02	-1.321071D-02	-2.463790D-03	1.014762D-03	8.111992D-06

SAMPLE, ADJOINT WEIGHTING, DISCONTINUOUS TRIAL FUNCTIONS

PAGE 166

REMOVE ALPHA/7/000000

REGION	GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP 5	GROUP 6
C2A1	6.610410-03	8.9591010-03	6.914270-03	3.8626210-03	8.0241930-04	6.9507700-03
AB411	3.7221930-04	9.4280460-04	1.2603040-03	7.7333470-04	1.4992760-04	1.4530430-03
AB421	1.9929340-04	9.0360400-04	6.9091470-04	9.0363240-04	1.1329090-04	1.3443390-03
AB431	9.0417440-05	2.4356770-04	3.4943140-04	9.0774770-04	7.9013020-04	1.2311330-03
C1A2	3.9580440-02	5.2970920-02	4.1309730-02	2.3249990-02	4.0740010-03	2.9580820-04
AB412	4.1904970-03	5.5960780-03	7.6033470-03	6.6030120-03	8.0190000-04	8.4634590-03
AB422	1.7443720-03	2.9440060-03	4.1422370-03	2.9726470-03	6.5408210-04	7.7017570-03
AB432	7.3073390-04	1.4340040-03	2.2215310-03	1.0273420-03	4.6470910-04	7.3309420-03
C1A3	7.0300490-02	1.0475390-01	8.2150030-02	4.5940210-02	8.0641000-03	5.8300320-04
AB413	9.8116140-03	1.3040590-02	1.5194070-02	9.0453340-03	1.6943790-03	1.6044600-04
AB423	3.0476020-03	6.0049540-03	8.3137720-03	5.0146730-03	1.2391110-03	1.4403340-04
AB433	1.4951960-03	3.2109740-03	4.4554010-03	3.5445310-03	8.3844990-04	1.3674120-04
C1A4	1.1923740-01	1.5383470-01	1.2139070-01	6.7444330-02	1.1036380-02	6.7471100-04
AB414	1.4012940-02	2.3070540-02	2.2370920-02	7.9251590-02	2.4455000-03	2.3367060-04
AB424	5.5252050-03	1.0920420-02	1.2232110-02	6.3130100-03	1.7943300-03	1.9990130-04
AB434	2.1233540-03	4.9475270-03	6.5172400-03	9.0784090-03	1.2334100-03	1.8000120-04
C2A5	1.4080190-01	1.4852230-01	1.5753420-01	8.7377040-02	1.5249940-02	1.0094000-03
AB415	1.0407660-02	2.9046020-02	1.7615000-02	1.4046170-02	2.6442060-03	2.9817600-04
AB425	6.0990000-03	1.3875250-02	1.5204130-02	1.0203370-02	2.0917440-03	2.2200900-04
AB435	2.5219020-03	4.1099920-03	6.1367950-03	4.2045700-03	1.6644000-03	2.1793230-04
C2A6	1.7740400-01	2.3406380-01	1.8059270-01	1.0394400-01	1.7074200-02	1.2007670-03
AB416	2.1504440-02	3.4403310-02	1.0504330-02	1.7904990-02	3.1040710-03	2.7371070-04
AB426	7.3704440-02	1.5790000-02	1.7843100-02	1.1344400-02	2.2523160-03	2.4205100-04
AB436	2.7030140-03	4.0340000-03	9.1031170-03	6.0531230-03	1.5690430-03	3.2707630-04
C2A7	2.3299730-01	3.0507070-01	2.4000170-01	1.2016320-01	2.1565390-02	1.4001730-03
AB417	2.4044790-02	4.9704150-02	3.1509040-02	2.1214400-02	3.6141230-03	3.1070970-04
AB427	8.1321430-03	1.0104000-02	2.0400970-02	1.3300990-02	2.3033720-03	2.6472440-04
AB437	2.9277420-03	7.0041100-03	1.0440030-02	8.0233200-03	1.7039100-03	2.4574690-04
C1G1	1.6500270-01	2.1340370-01	1.4440000-01	6.4579700-02	1.3234490-02	8.1782020-04
AB418	1.5109040-02	2.5420530-02	2.1032140-02	1.3025370-02	2.7426050-03	2.0260940-04
AB428	4.9436120-03	1.1120940-02	1.2409440-02	5.3720910-03	1.0423700-03	1.3004390-04
AB438	1.7370760-03	4.7203540-03	6.3709740-03	9.0319240-03	1.1244460-03	1.6506350-04
C2G2	1.0032290-01	2.2039140-01	1.7737000-01	7.7700740-02	1.3009350-02	8.2401020-04
AB419	1.6140590-02	2.5700540-02	2.2707400-02	1.5050110-02	3.0044420-03	4.7430180-04
AB429	5.1432010-02	1.1157000-02	1.2790430-02	9.8040770-03	2.7492370-03	3.7032720-04
AB439	1.7095530-03	4.4001010-03	4.7370910-03	9.4000120-03	1.0910400-03	3.4437010-04
C2G3	2.1700930-01	2.0447370-01	2.2770230-01	1.1029970-01	1.0426330-02	1.3427050-03
AB411	1.0025240-02	3.2721300-02	2.0903200-02	1.0104010-02	3.1404750-03	2.4792400-04
AB421	1.0144000-03	7.4023470-02	1.6504470-02	1.1230140-02	1.1601350-03	2.0217700-04
AB431	2.0270420-03	5.0501130-03	8.4022700-03	6.7164310-03	1.4608200-03	1.0144700-04
AB412	3.0030110-02	1.2270740-01	1.1329700-01	6.7504400-02	1.2409400-02	1.1753150-03
AB422	1.0739700-02	2.1350000-02	1.7627040-02	1.2993400-02	2.0007400-03	1.4035170-04
AB433	5.7907250-03	8.0543000-03	1.0303740-02	7.7940520-03	1.4449270-03	1.1074040-04
AB414	1.0002770-03	3.7335050-03	6.0533460-03	6.6079910-03	9.4713740-04	1.1119340-04
AB424	1.9000100-02	4.6555510-02	3.6524470-02	3.0250310-02	0.9524070-03	1.1070430-03
AB434	1.2520130-02	1.4004750-02	2.1200130-02	7.0477310-03	1.2231340-03	7.1000340-03
P023	3.7404010-03	5.9112200-03	4.4091910-03	6.4074200-03	8.4900440-04	6.4720400-03
AB426	3.2234000-03	2.4252230-03	2.4709210-03	2.9260000-03	6.0200100-04	4.3912770-03
REF00	7.7303340-03	9.9100200-03	1.1957430-02	9.5530950-03	3.3274040-03	2.8293440-03
REFAX	3.4909710-03	1.4137570-02	3.2943540-02	3.1571000-02	1.5013340-02	2.0043410-03

SCATTERING						
REGION	GROUP	GROUP	GROUP	GROUP	GROUP	GROUP
	1	2	3	4	5	6
C1A1	0.0	9.1324040-03	1.2626010-03	3.9944100-03	6.7698040-04	4.7184590-03
ADA11	0.0	2.9670030-04	8.1789010-04	7.8996370-04	1.5422210-04	1.5451620-03
ADA21	0.0	1.5054270-04	4.4221700-04	4.3740170-04	1.0450010-04	1.2400110-03
ADA31	0.0	7.2531900-03	2.1780310-04	2.3420420-04	4.5009900-03	9.3097230-04
C1A2	0.0	3.8773040-02	4.3430400-02	7.3472930-02	4.0479040-03	2.8103370-04
ADA12	0.0	3.3440370-03	4.7600000-03	4.7600000-03	9.3100120-04	9.1020310-03
ADA22	0.0	1.1094130-03	2.4002310-03	2.4031400-03	6.2100230-04	7.3499400-03
ADA32	0.0	7.7023050-04	1.2649500-03	1.4329130-03	3.0193200-04	5.3704740-03
C1A3	0.0	5.0052500-02	6.9095300-02	4.5900100-02	8.0193750-03	5.3047070-04
ADA13	0.0	7.8266640-03	1.2327000-02	9.3027040-03	1.6314540-03	1.7500520-04
ADA23	0.0	7.0442040-03	4.1311900-03	5.3040000-03	1.2174010-03	1.6110740-04
ADA33	0.0	1.1092500-03	2.8744030-03	2.8754700-03	7.4313240-04	1.0374210-04
C1A4	0.0	8.9478750-02	1.2418570-01	6.9405720-02	1.1010120-02	4.2283000-04
ADA14	0.0	1.1793050-02	2.0340070-02	1.3060000-02	2.4415410-03	2.4020400-04
ADA24	0.0	4.4214220-03	7.0404270-03	7.7003440-03	1.7445400-03	1.9750540-04
ADA34	0.0	1.7037170-03	4.4200240-03	4.2094030-03	1.0914430-03	1.4722120-04
C1A5	0.0	1.1950120-01	1.4279700-01	9.0101730-02	1.5260140-02	1.0427440-03
ADA15	0.0	1.4744300-02	2.4029740-02	2.7212340-02	3.2712960-03	3.0071490-04
ADA25	0.0	5.3993040-03	1.2315400-03	9.7400300-03	2.1442940-03	2.7704950-04
ADA35	0.0	2.0242400-03	5.5120770-03	5.2400010-03	1.3342970-03	1.7550400-04
C1A6	0.0	1.1017740-01	1.0441900-01	1.0787570-01	1.0100500-02	1.2550820-03
ADA16	0.0	1.6742730-02	3.0305520-02	1.9253000-02	3.4040900-03	3.2003970-04
ADA26	0.0	5.0072040-03	1.4019630-02	1.1164420-02	2.4174190-03	2.1046040-04
ADA36	0.0	2.1699100-03	6.1034020-03	3.8935440-03	1.4791100-03	1.0910970-04
C1A7	0.0	1.0009520-01	2.1074340-01	1.3739490-01	2.2439530-02	1.5150400-03
ADA17	0.0	1.6203010-02	2.6144430-02	2.2463440-02	4.3752440-03	3.9091220-04
ADA27	0.0	4.3143070-03	1.6000240-02	1.2939230-02	2.8261950-03	2.9924370-04
ADA37	0.0	2.3513230-03	6.9530000-03	6.9020710-03	1.7301530-03	2.1749990-04
C1A8	0.0	1.8174040-01	1.7025030-01	9.0490030-02	1.3074040-02	4.3002890-04
ADA18	0.0	1.2070670-02	2.2475010-02	1.3001070-02	2.7954470-03	2.5005530-04
ADA28	0.0	3.0447070-03	8.0074750-03	6.0474730-03	1.7000400-03	1.9351020-04
ADA38	0.0	1.3997940-03	4.2170070-03	4.2700230-03	1.0951710-03	1.3860210-04
C1A9	0.0	1.3000000-01	1.8126250-01	9.2307010-02	1.3297110-02	6.4755410-04
ADA19	0.0	1.2954230-02	2.2974430-02	1.3454730-02	2.0679420-03	2.4939000-04
ADA29	0.0	4.1343900-03	9.0030400-03	7.0322530-03	1.8230020-03	2.0020930-04
ADA39	0.0	7.4293000-03	4.1625940-03	4.2103700-03	1.1103160-03	1.4650210-04
C1A10	0.0	1.4431710-01	2.2401930-01	1.2400510-01	1.9501730-02	1.2147030-03
ADA110	0.0	1.4422700-02	2.9142940-02	1.0002640-02	3.0004490-03	3.3020470-04
ADA210	0.0	4.7443590-03	1.2401090-02	1.0374330-02	2.4102740-03	2.3473720-04
ADA310	0.0	1.6790000-03	5.2200040-03	5.5990120-03	1.4441040-03	1.6145540-04
ADA111	0.0	6.5151700-02	1.0004340-02	7.0279300-02	1.3754130-02	1.3440770-03
ADA211	0.0	1.3312920-02	1.9900000-02	1.1015790-02	2.6339410-03	2.4344920-04
ADA311	0.0	4.0045450-03	3.1794100-03	4.4004000-03	1.0427140-03	1.7770940-04
ADA112	0.0	1.5471270-03	3.3494700-03	3.4321900-03	1.0034030-03	1.2533300-04
ADA212	0.0	1.4043370-02	4.0943340-02	3.4034630-02	7.9632730-03	9.9302310-04
ADA312	0.0	1.0134410-02	1.2932040-02	7.0034140-03	1.0402220-03	1.4970960-04
ADA113	0.0	3.0302110-03	5.3344170-03	4.1339020-03	1.0400500-03	1.0046490-04
ADA213	0.0	9.4947040-04	2.1816440-03	2.1895220-03	4.3312150-04	7.6430200-03
ADA313	0.0	7.1813710-03	9.6474720-03	9.3740070-03	4.5444470-03	6.7220620-04
ADA114	0.0	3.4473070-03	3.7331730-02	2.9145470-02	1.7044350-02	3.4470330-03

REGION						
REGION						
REGION	GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP 5	GROUP 6
CEA1	7.1614450-03	4.6157620-03	3.7677950-04	2.0944830-03	2.1262170-07	2.4472440-04
CEA2	9.1316770-04	2.4635440-04	2.1737640-03	1.2083770-06	1.2264860-08	1.4118980-09
CEA3	1.4718210-04	1.2704540-04	1.0369980-03	3.7445780-07	5.8519190-09	6.7354770-10
CEA4	7.3397540-03	4.8604480-03	3.9635320-04	2.2091270-07	2.2389870-09	2.5763250-10
CEA5	4.2852390-02	2.7625610-02	2.2545590-03	1.2532890-04	1.2722780-06	1.4443740-07
CEA6	2.8521940-03	2.8387220-03	1.9006030-04	8.3617160-06	8.4681040-08	9.7466490-09
CEA7	1.1953810-03	2.07962520-04	6.2891630-03	3.4960890-06	3.5497600-08	4.0849180-09
CEA8	4.7873920-04	3.0862840-04	2.5187530-03	1.4801520-06	1.4213660-08	1.6359730-09
CEA9	8.4405090-02	5.4756270-02	4.4670920-03	2.4832160-04	2.5206400-06	2.9014520-07
CEA10	4.1891850-03	3.9384030-03	3.2141770-04	1.7867320-05	1.8138040-07	2.0876630-08
CEA11	2.4427910-03	1.5876850-03	1.2957290-04	7.2028410-06	7.3119730-08	8.4239790-09
CEA12	9.6283420-04	6.2070950-04	5.0656840-05	2.8159680-06	2.8586340-08	3.2902470-09
CEA13	1.2904880-01	8.0615100-02	6.5799940-03	3.6572590-04	3.7126720-06	4.2732330-07
CEA14	1.0112940-02	6.5195020-03	5.1206430-04	2.9576970-05	3.0025110-07	3.4558480-08
CEA15	3.5466220-03	2.2865240-03	1.8660610-04	1.0373270-05	1.0530440-07	1.2120380-08
CEA16	1.3624470-03	8.7832770-04	7.1681370-05	3.9847030-06	4.0450760-08	4.6558260-09
CEA17	1.4178130-01	1.0429540-01	8.5114690-03	4.7315610-04	4.8032500-06	5.5784740-07
CEA18	1.1047530-02	7.1220030-03	5.8123510-04	3.2310340-06	3.2799880-08	3.7752210-09
CEA19	4.2578710-03	2.7448180-03	2.2401600-04	1.2452850-05	1.2641530-07	1.4558770-08
CEA20	1.4124190-03	1.0394780-03	8.832900-05	4.7157690-06	4.7872350-08	5.5100410-09
CEA21	1.9308000-01	1.2442720-01	1.0158370-02	5.6449440-04	5.7325030-06	6.5980310-07
CEA22	1.2076300-02	7.7852210-03	4.3536110-04	3.5319150-05	3.5894290-07	4.1267780-08
CEA23	4.5540120-03	2.9358320-03	2.3959660-04	1.3318960-05	1.3920760-07	1.5562210-08
CEA24	1.6987630-03	1.0951400-03	8.9374680-05	4.9483140-06	5.0435910-08	5.8051020-09
CEA25	2.4452610-01	1.5879890-01	1.2998760-02	7.2042160-04	7.3133490-06	8.4175860-07
CEA26	1.3355320-02	8.4097610-03	7.0265280-04	3.9059840-05	3.9651650-07	4.5438490-08
CEA27	4.5298890-03	3.1781470-03	2.5937230-04	1.4418280-05	1.4636730-07	1.6846670-08
CEA28	1.6159790-03	1.1646160-03	9.5437450-05	5.3052820-06	5.3856440-08	6.1988240-09
CEA29	1.4906400-01	1.2833040-01	1.0473200-02	5.8219560-04	5.9101660-06	6.8025190-07
CEA30	7.7841660-03	5.0142240-03	4.0954320-04	2.2766140-05	2.3111080-07	2.6600530-08
CEA31	2.8860700-03	1.8089870-03	1.4763560-04	8.2068170-06	8.3311620-08	9.5890510-09
CEA32	1.0219800-03	6.5845870-04	3.3737600-05	2.9872250-06	3.0324850-08	3.4903480-09
CEA33	1.7884820-01	1.2620620-01	1.0462900-02	5.8162310-04	5.9043540-06	6.7958790-07
CEA34	7.1666640-03	4.4201400-03	3.7705510-04	2.0960150-05	2.1277730-07	2.4690370-08
CEA35	2.5311120-03	1.6317380-03	1.3316740-04	7.4026570-06	7.5146170-08	8.6494490-09
CEA36	9.1313000-04	5.8867960-04	4.8062840-05	2.6706580-06	2.7111220-08	3.1204640-09
CEA37	3.7594520-01	1.7499110-01	1.4281230-02	7.9388070-04	8.0590910-06	9.2754010-07
CEA38	9.7499430-03	6.1285480-03	5.1296400-04	2.8515320-05	2.8973730-07	3.3318010-08
CEA39	3.4673720-03	2.2353070-03	1.8242610-04	1.0140900-05	1.0294550-07	1.1848880-08
CEA40	1.2544840-03	8.0357090-04	4.5580380-05	3.6453540-06	3.7007490-08	4.2593570-09
CEA41	4.8427390-02	2.4042290-02	2.1269740-03	1.1821840-04	1.2002400-06	1.3815060-07
CEA42	6.1368750-03	3.9542540-03	3.2267460-04	1.7949310-05	1.8220250-07	2.0971250-08
CEA43	2.0791870-03	1.3403360-03	1.0938440-04	6.0806930-06	6.1728240-08	7.1048160-09
CEA44	7.4412210-04	4.7971250-04	3.9149910-05	2.1763080-06	2.2092820-08	2.5428530-09
CEA45	1.3612980-02	8.3890680-03	6.8464180-04	3.8058420-05	3.8635260-07	4.448650-08
CEA46	3.5671880-03	2.2626520-03	1.8465770-04	1.0264980-05	1.0420490-07	1.1993830-08
CEA47	1.1774770-03	7.5908320-04	6.1949680-05	3.4437270-06	3.4959040-08	4.0237370-09
CEA48	4.2543170-04	2.7426400-04	2.2383610-05	1.2442510-06	1.2631030-08	1.4538140-09
CEA49	0.0	0.0	0.0	0.0	0.0	0.0
CEA50	0.0	0.0	0.0	0.0	0.0	0.0

SAMPLE, ADJOINT WEIGHTING, DISCONTINUOUS TRIAL FUNCTIONS

PAGE 147

120

TOTAL BALANCE

REGION	GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP 5	GROUP 6
CYAL	-3.5734060-04	-5.8161990-04	5.7123690-04	2.2197310-05	4.0739530-04	-5.1726430-07
ABA11	1.6424000-03	7.8954010-04	-7.3272960-04	-7.3498000-05	-1.8507630-05	-1.1625210-06
ABA12	2.3496810-04	-5.4956890-05	-4.5294820-05	-4.8714800-05	-1.2271770-05	-1.5554260-06
ABA13	7.8648890-05	-2.2027470-05	-1.7376538-05	-2.1231940-05	-7.0846450-06	-7.8261130-07
CIA2	-4.3687610-04	-3.6953280-03	3.2783890-03	1.5146040-04	2.4372090-05	-3.0430980-06
ABA12	8.0089950-04	8.0148320-03	-4.2974420-03	-3.3460530-04	-7.6824500-05	-3.4983460-06
ABA22	-1.6462300-04	2.2318390-03	-2.9642150-04	-1.5738510-04	-4.6619660-05	-5.9951130-06
ABA32	-4.6744170-05	4.7652740-04	-1.1905210-04	-8.9877220-05	-3.1298040-05	-5.2079660-06
CIA3	1.9169670-04	-2.1831630-03	5.6674420-03	3.0210220-04	3.2322230-05	-5.3549230-06
ABA13	-7.4074130-06	2.3123030-03	-6.5044180-03	-5.2421880-04	-1.0173760-04	-3.4298790-06
ABA23	-1.5395880-04	-4.2645910-04	-1.1667970-04	-1.8981770-04	-6.5220220-05	-8.7290890-06
ABA33	-4.9219700-05	-2.7864720-04	-7.1040140-05	-1.0998790-04	-4.3673060-05	-7.6889260-06
CIA4	4.1045170-04	1.7132000-05	4.4707440-03	5.0554010-04	8.7646270-06	-6.3974720-06
ABA14	-4.6121020-04	-3.2760070-03	-4.4028730-03	-6.3620590-04	-1.2134180-04	-1.1000760-05
ABA24	-6.9743420-05	-5.4041840-04	2.2094780-04	-6.3378000-05	-4.0995990-05	-6.0939000-06
ABA34	-2.3986030-05	-2.2347870-04	3.7552920-05	-4.7022400-05	-2.6633600-05	-5.5139550-06
CIA5	9.7199930-04	3.4307550-03	3.7841230-03	-8.5824410-05	-6.9559050-05	-6.4903080-06
ABA15	-1.8561890-03	-4.8219540-03	-3.2235560-03	2.2089630-04	1.2393560-04	1.3483440-05
ABA25	1.2822820-04	-2.5893100-04	3.6176890-04	1.0338270-04	2.3447440-05	1.4475090-06
ABA35	3.8456470-05	-9.6026830-05	2.3770180-04	6.6887830-05	1.7152870-05	9.4106710-07
CIA6	7.4731540-04	3.4125960-03	-2.1857210-03	-7.8737280-04	-1.7851660-04	-5.3442150-06
ABA16	-2.0332460-03	-7.4799470-05	2.7927380-03	1.6786430-03	4.0892200-04	3.0399980-05
ABA26	2.6884170-05	-3.7703320-04	2.4637690-04	4.2570110-04	1.7004260-04	1.5436860-05
ABA36	1.3617410-05	-9.3963450-05	1.2530510-04	2.4500110-04	9.6515490-05	1.1309870-05
CIA7	-1.3942270-03	1.3898470-04	-1.1954580-02	-1.5478810-03	-2.3436220-04	6.3073530-06
ABA17	2.5617680-03	-2.9353760-03	1.2362250-02	2.3530440-03	5.6811510-04	4.6004330-05
ABA27	4.4375220-04	1.6791580-04	8.5617940-05	5.8334670-04	2.7367840-04	3.6895110-05
ABA37	1.4456140-04	1.3212740-04	1.3383790-04	3.8687910-04	-1.9234520-04	3.3411940-05
CIA8	-2.0273540-03	-8.5542590-04	-1.1485030-02	1.0920540-04	2.2808430-04	3.7669280-05
ABA18	4.8583490-03	2.7298990-03	1.2571130-02	1.0162400-03	1.9984180-04	1.9878100-05
ABA28	3.8768240-04	3.2154950-04	1.0499180-04	5.9304770-04	2.8385480-04	4.4191790-05
ABA38	1.2898410-04	1.7683020-04	1.6666090-04	3.4616980-04	2.0531540-04	4.3149580-05
CIA9	-4.7493170-04	-1.4410510-04	-1.2402200-02	1.8036000-03	4.7374830-04	4.7712840-05
ABA19	-1.4544370-03	1.8187880-03	1.2757120-02	-6.5712040-03	-2.3024040-03	-3.1753110-04
ABA29	-1.1214710-03	-5.3808710-04	-8.7927810-04	-2.0002680-03	-1.4828140-03	-1.7575720-04
ABA39	-3.6098210-04	-2.4062890-04	-4.4974100-04	-1.1755130-03	-7.8090150-04	-1.5522240-04
CIA1	-1.4611110-03	1.3872740-03	2.1675630-02	-3.3358520-04	1.8739240-04	6.4353180-05
ABA21	1.2360030-02	7.6779850-03	2.2927770-02	1.7517280-03	4.4002210-04	3.6791880-05
ABA31	2.0224970-03	1.7465600-03	3.7879510-04	9.4810800-04	4.6389480-04	7.0938940-05
CIA2	4.5987640-04	7.7448680-04	4.1222880-04	6.9704490-04	3.4357550-04	7.1576040-05
ABA22	7.8251690-03	4.3869560-03	-7.4759250-03	-4.9711490-04	-6.1295530-04	-4.0536260-05
ABA32	-2.2012800-02	-4.2799880-03	8.3950340-03	-1.0814990-03	8.5472870-04	1.4755170-04
CIA3	-2.7576400-03	9.3939420-04	-2.7912900-04	-8.0846680-04	2.5536750-04	4.4243890-05
ABA23	-8.1834680-04	8.0306470-03	-5.2886110-04	-4.2844750-04	1.2348380-04	4.6839710-05
ABA33	4.0261340-03	8.4061180-03	-1.1294420-03	3.4721160-05	-5.0510900-04	-7.7947840-05
CIA4	-1.5521680-02	-1.3836510-02	-1.3581640-03	-8.5911820-04	7.6944790-04	1.4453350-04
ABA24	-1.1945600-03	7.5643430-05	-2.1665150-04	-2.3347550-04	2.2018990-04	4.6390430-05
ABA34	-1.8787750-04	-1.4429040-04	-3.8264960-04	-2.3744990-04	1.1292440-04	3.0557200-05
CIA5	-4.8121890-03	1.6120640-03	1.5997350-03	8.3547750-04	8.1699030-06	-1.2140190-04
ABA25	-2.2198060-05	7.3483340-04	1.7892810-04	3.7573720-05	2.3424300-04	1.7069920-04

SAMPLE, ADJOINT WEIGHTING, DISCONTINUOUS TRIAL FUNCTIONS

PAGE 148

REGION AVERAGED FISSION SOURCE

REGION	GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP 5	GROUP 6
CZA1	1.0368910-08	6.4845150-07	5.4553120-08	3.0325590-09	3.0785060-11	3.5433180-12
ABA11	1.7946510-07	1.1360560-07	9.4420530-09	5.2487530-10	5.3282790-12	6.1327750-13
ABA21	8.5614020-08	5.5192720-08	4.5043430-09	2.5039240-10	2.5418620-12	2.9256470-13
ABA31	3.2749970-08	2.1112900-08	1.7230480-09	9.5782710-11	9.7233850-13	1.1191490-13
CZA2	1.0340800-06	6.4863920-07	5.4405210-08	3.0243370-09	3.0701600-11	3.5337110-12
ABA12	2.0648060-07	1.3311170-07	1.0863400-08	6.0388680-10	6.1301650-12	7.0599640-13
ABA22	8.6537930-08	5.5788330-08	4.5529520-09	2.5309450-10	2.5692920-12	2.9572190-13
ABA32	3.4657650-08	2.2342720-08	1.8234160-09	1.0134200-10	1.0289780-12	1.1843390-13
CZA3	1.0244460-06	6.4042890-07	5.3898390-08	2.9961630-09	3.0415590-11	3.5007920-12
ABA13	2.2113400-07	1.4253820-07	1.1634350-08	4.4674290-10	6.5654190-12	7.5567060-13
ABA23	8.9145570-08	5.7469400-08	4.8901460-09	2.6072100-10	2.6467130-12	3.0463290-13
ABA33	3.4851680-08	2.2467800-08	1.8336240-09	1.0192950-10	1.0367390-12	1.1909700-13
CZA4	1.0058570-06	6.4844520-07	5.2920380-08	2.9617970-09	2.9863690-11	3.4372690-12
ABA14	2.4403700-07	1.5733310-07	1.2839330-08	7.1372660-10	7.2494060-12	8.3393610-13
ABA24	8.5588910-08	5.5178530-08	4.3090220-09	2.5031490-10	2.5411160-12	2.9247890-13
ABA34	3.2877430-08	2.1193060-08	1.7297340-09	9.6155490-11	9.7612780-13	1.1239050-13
CZA5	9.7599050-07	6.2919610-07	5.1349640-08	2.8544490-09	2.8877180-11	3.3352330-12
ABA15	1.9994360-07	1.2889750-07	1.0519400-08	5.8476820-10	5.9362820-12	6.8125780-13
ABA25	7.7061020-08	4.9678960-08	4.0543500-09	2.2537770-10	2.2879250-12	2.6333690-13
ABA35	2.9182330-07	1.8812950-08	1.5353470-09	8.5368560-11	8.6641710-13	9.9723390-14
CZA6	9.3184710-07	6.0073300-07	4.9026930-08	2.7253410-09	2.7666340-11	3.1843570-12
ABA16	1.7484880-07	1.1271960-07	9.1991820-09	5.1137430-10	5.1912230-12	5.9750250-13
ABA26	6.5936030-08	4.2506920-08	3.4690600-09	1.9294980-10	1.9576260-12	2.2532900-13
ABA36	2.4595830-08	1.5856170-08	1.2940410-09	7.1934570-11	7.3027470-13	8.4050150-14
CZA7	8.6336770-07	5.5658650-07	4.5423680-08	2.5250620-09	2.5633200-11	2.9503490-12
ABA17	1.4043030-07	9.0531070-08	7.3883480-09	4.1871160-10	4.1693450-12	4.7988580-13
ABA27	5.1837450-08	3.3418000-08	2.7272630-09	1.5160720-10	1.5390430-12	1.7714170-13
ABA37	1.9073870-08	1.2296330-08	1.0035180-09	5.5784490-11	5.6629900-13	6.5180230-14
CZA8	9.3911340-07	6.0541740-07	4.9408830-08	2.7465930-09	2.7882070-11	3.2091870-12
ABA18	1.1016910-07	7.1022610-08	5.7962400-09	3.2220780-10	3.2708960-12	3.7647560-13
ABA28	3.9714140-08	2.3602480-08	2.0894490-09	1.1615060-10	1.1791060-12	1.3571320-13
ABA38	1.4455670-08	9.3171250-09	7.6854480-10	4.2278010-11	4.2918570-13	4.9398680-14
CZA9	8.0695660-07	5.2822000-07	4.2455770-08	2.3600780-09	2.3998370-11	2.7575740-12
ABA29	8.7241730-08	5.4242030-08	4.5899600-09	2.5515230-10	2.5901880-12	2.9812700-13
ABA39	3.0611830-08	1.9963430-08	1.6210780-09	9.0114280-11	9.1479640-13	1.0529180-13
ABA32	1.1113990-08	7.1661360-09	5.8483680-10	3.2518550-11	3.3063130-13	3.7886140-14
CZC1	5.9106750-07	3.8104290-07	3.1897370-08	1.7286790-09	1.7588660-11	2.0198270-12
ABC11	6.3691480-08	4.1059730-08	3.3509500-09	1.8627630-10	1.8909860-12	2.1764990-13
ABC21	2.2650600-08	1.4402140-08	1.1916980-09	6.6245420-11	6.7249130-13	7.7482810-14
ABC31	8.1426640-09	5.2493260-09	4.2840370-10	2.3814580-11	2.4754800-13	2.7825560-14
RB11	9.7840010-08	6.3074440-08	5.1475790-09	2.8614930-10	2.9048490-12	3.3434600-13
RB12	4.4556320-08	2.8724990-08	2.3442070-09	1.3031230-10	1.3228660-12	1.5226020-13
RB13	1.5095200-08	9.7314110-09	7.9419280-10	4.4168420-11	4.4817330-13	5.1584120-14
RB14	5.4026430-09	3.4829170-09	2.8424580-10	1.5808920-11	1.6049330-13	1.8467190-14
RB21	2.8547240-08	1.8403520-08	1.5819330-09	8.3491130-11	8.4756130-13	9.7533120-14
RB22	2.3098800-08	1.4895180-08	1.2152790-09	6.7556270-11	6.8579840-13	7.8934630-14
RB23	7.7427400-09	6.9957180-09	4.0770650-10	2.2864040-11	2.3067430-13	2.6491230-14
RB24	2.7998870-09	1.8059800-09	1.4730620-10	8.1867320-12	8.3828020-14	9.5679190-15
REFR0	0.0	0.0	0.0	0.0	0.0	0.0
REFAX	0.0	0.0	0.0	0.0	0.0	0.0

SAMPLE ADJUNCT WEIGHTING, DISCONTINUOUS TRIAL FUNCTIONS

PAGE 149

TOTAL TERMS SUMMED OVER GROUPS		REGION	LEAKAGE	REMOVAL	SCATTERING	FISSION	Absorption	EXT SOURCE	BALANCE
C2A1	2.5117160-03	2.6990040-02	1.7073080-02	1.2178170-02	4.9241030-03	0.0	-3.6210960-04		
ABA11	-2.3281320-03	3.5193010-03	2.0763700-03	7.0240300-04	1.4430120-03	0.0	1.5763330-03		
ABA21	-4.3497000-04	2.0244560-03	1.1561100-03	3.3512070-04	8.6834420-04	0.0	1.0017440-04		
ABA31	-3.8244940-04	1.5040960-03	6.0379000-04	1.2019300-04	5.0089700-04	0.0	4.1416680-04		
C2A2	1.4094390-02	1.0153150-01	1.0216090-01	7.2859310-02	5.9362570-02	0.0	-9.0102320-04		
ABA12	-9.1303390-03	2.2928020-02	1.4073110-02	4.8404130-03	8.0549050-03	0.0	1.1021220-03		
ABA22	-3.7198010-03	1.2518040-02	7.3966640-03	2.0124330-03	5.1827760-03	0.0	5.4001640-04		
ABA32	-2.3675750-03	6.7325720-03	3.7351800-03	8.1397110-04	2.9973040-03	0.0	1.8036790-04		
C2A3	2.1925080-02	3.1951310-01	2.0232040-01	1.4436090-01	1.1759280-01	0.0	4.1047362-03		
ABA13	-2.2064130-03	4.9748740-02	3.1450870-02	1.0387000-02	1.8109270-02	0.0	-3.5444440-03		
ABA23	-5.0732990-03	2.6244950-02	1.5045070-02	4.1873340-03	1.0401480-02	0.0	-1.1800640-03		
ABA33	-3.7487930-03	1.3761330-02	7.8230970-03	1.4370440-03	5.4384300-03	0.0	-5.6029640-04		
C2A4	2.9177460-02	4.7083960-01	2.9770310-01	2.1261290-01	1.7313650-01	0.0	9.3025020-03		
ABA14	1.1043010-03	7.6220330-02	4.8901540-02	1.7144420-02	2.7318790-02	0.0	-1.1309740-02		
ABA24	-8.5040480-03	3.8955660-02	2.3064440-02	6.0304450-03	1.5058720-02	0.0	-5.1964710-04		
ABA34	-5.9520540-03	2.0308430-02	1.1444440-02	2.1044440-03	6.5273780-03	0.0	-2.49008180-04		
C2A5	4.1733420-02	4.9508440-01	3.8404340-01	7.7506660-01	2.2381680-01	0.0	8.2270030-03		
ABA15	-2.7296990-03	9.4929070-02	6.1940540-02	1.0785450-02	3.2968320-02	0.0	-1.1943380-02		
ABA25	-1.1719700-02	4.8301790-02	2.9817870-02	7.2933980-03	1.8505920-02	0.0	3.5924590-04		
ABA35	-7.8954170-03	2.4717740-02	1.4297780-02	2.7414970-03	1.0419040-02	0.0	1.4311320-04		
C2A6	3.9279680-02	3.2620900-01	4.3982860-01	3.2828220-01	2.8846160-01	0.0	1.0029570-03		
ABA16	-1.1724290-02	1.0728320-01	7.0520080-02	2.0532410-02	3.6743160-02	0.0	-6.6024710-03		
ABA26	-1.3576250-02	3.4343790-02	3.3770260-02	7.7679090-03	2.0573500-02	0.0	7.8937840-04		
ABA36	-9.0449700-03	2.7509400-02	1.3837440-02	3.4803030-03	1.1471940-02	0.0	4.4778530-04		
C2A7	9.5442680-02	9.2738290-01	5.9299860-01	4.1881330-01	7.3639430-01	0.0	-1.4985760-02		
ABA17	-3.5231440-03	1.2542480-01	8.2500250-02	2.2707130-02	4.2844500-02	0.0	1.4977800-02		
ABA27	-1.7126910-02	6.2945880-02	1.8667270-02	8.3810890-03	2.3878620-02	0.0	1.9910080-03		
ABA37	-1.1222620-02	3.1443200-02	1.8184080-02	3.0041940-03	1.3249200-02	0.0	1.0231630-03		
C2A8	1.1044430-01	6.4282870-01	4.0240900-01	3.3045640-01	2.4021890-01	0.0	-1.3992850-02		
ABA18	-1.4865000-02	7.0336310-02	5.1889470-02	1.3236980-02	2.6446440-02	0.0	2.1391330-02		
ABA28	-1.1813120-02	3.6728270-02	2.3903230-02	4.7709910-03	1.4825010-02	0.0	1.7367180-03		
ABA38	-7.5892900-03	1.9348840-02	1.1124210-02	1.7366500-03	8.2226310-03	0.0	1.0951300-03		
C2B2	7.3436110-02	7.0094440-01	4.2861500-01	3.3812350-01	7.7377960-01	0.0	-1.0476170-02		
ABA19	-2.5241270-02	8.4380410-02	5.2741150-02	1.2185080-02	3.1639250-02	0.0	9.7309060-03		
ABA29	-7.6893330-03	4.2103430-02	2.4015590-02	4.3034640-03	1.8087840-02	0.0	-9.9151760-03		
ABA39	-5.6013020-03	2.1382180-02	1.1043210-02	1.5515730-03	1.0318970-02	0.0	-3.1723680-03		
C2C1	1.5384440-01	3.6893740-01	4.3842010-01	4.6151840-01	3.3013210-01	0.0	-2.4620840-02		
ABC11	-6.1754600-02	1.0137840-01	6.4378790-02	1.6377230-02	3.5059840-02	0.0	6.5104320-02		
ABC21	-1.9290790-02	4.9953120-02	3.0467580-02	5.8953610-03	1.9485540-02	0.0	5.6729940-03		
ABC31	-1.1837940-02	2.4854180-02	1.4091630-02	2.1197240-03	1.0740550-02	0.0	1.9847850-03		
AB11	-7.5045670-02	4.0009000-01	7.5939370-01	6.8736230-02	1.4064410-01	0.0	2.7659540-01		
AB12	6.2746240-03	7.2861910-02	4.8774100-02	1.0434160-02	7.40093810-02	0.0	-1.9974970-02		
AB13	-7.2739990-03	3.4562810-02	2.1101970-02	3.5349790-03	1.3380850-02	0.0	-2.5884380-03		
AB14	-4.3053770-03	1.4891310-02	4.4740820-03	1.2651860-03	7.4117080-03	0.0	-1.0472740-03		
AB21	-4.1108070-02	1.7065080-01	1.9078070-01	2.2129100-02	7.0870110-02	0.0	1.5059470-02		
AB22	1.8836170-02	4.6999940-02	3.1939580-02	5.9474790-03	1.4040360-02	0.0	-7.7944960-02		
AB23	-5.1202440-03	2.2081450-02	1.3704140-02	2.0919930-03	8.3775550-03	0.0	-1.2644430-03		
AB24	-2.8917450-03	1.0713100-02	6.0746780-03	7.2339310-04	4.6344350-03	0.0	-1.0279410-03		
REFR0	-1.0717890-02	4.2170090-02	3.1424440-02	0.0	1.07456270-02	0.0	-2.7736270-03		
REFR1	-3.4931160-02	1.0444360-01	7.0554940-02	0.0	1.3407600-02	0.0	1.3260720-03		

TOTAL TERMS SUMMED OVER REGIONS

GROUP	LEAKAGE	REMOVAL	SCATTERING	FISSION	ABSORPTION	EXT SOURCE	BALANCE
1	2.853484D-03	1.729437D 00	0.0	1.719844D 00	1.729437D 00	0.0	-2.850446D-02
2	2.644910D-02	2.425088D 00	1.349034D 00	1.108732D 00	1.074034D 00	0.0	1.033784D-03
3	2.953596D-02	2.074339D 00	2.018361D 00	9.844491D-02	5.405790D-02	0.0	4.447091D-03
4	1.318071D-02	1.209089D 00	1.216204D 00	5.829975D-03	-4.794415D-03	0.0	-1.777467D-03
5	2.309350D-01	2.247157D-01	2.328419D-01	5.104184D-03	-4.146245D-03	0.0	5.887718D-03
6	5.638948D-04	2.042248D-02	2.192044D-02	5.877448D-04	-1.093784D-03	0.0	5.357405D-04

TOTAL LEAKAGE = 8.748947D-01
 TOTAL REMOVAL = 8.768703D 01
 TOTAL SCATTER = 8.683782D 01
 TOTAL FISSION = 8.292419D 01
 TOTAL ABSORPTN = 8.794491D 01
 TOTAL BALANCE = -8.142448D-01

TIME FOR EXECUTION OF SYNOUT IS 0.2318 MINUTES.
 THE FOLLOWING DATA SETS WERE OPEN BUT HAVE BEEN REMOVED
 DATA SET NAME QSRM

SCDD01 23

THE TOTAL RUNNING TIME FOR THE EXECUTION OF SYN2D WAS 2.0305 MINUTES.
 MODULE AJCOO9 HAS JUST BEEN LEFT REMINING.

TIME FOR THE EXECUTION OF SYPO08 IS 3.0027 MINUTES.
 MODULE SYPO08 HAS JUST BEEN EXITED FROM.

and the reactor region and composition subjects assigned to each are printed. The page shown contains this data for the z -direction mesh interval, the rest are in the same format.

For XY geometry there will be a page giving buckling information. Each reactor region is listed by number, followed by the number of the composition assigned to that region. Then the buckling and transverse half-height for each reactor region is given. If the buckling is zero the half-height is set to 0.5 and should be ignored. The reactor region and composition numbers used here are consistent with those used on page 2.

Pages 3 and 4 contain all of the macroscopic composition cross sections for every energy group for one composition. Page 3 contains the diffusion coefficient (D) (σ_{TR}), removal (σ_R), nu times fission ($\nu \sigma_f$), fission spectrum (χ), and fission (σ_f). If a composition is nonfissionable, only the first two columns appear. Page 4 contains the scattering (σ_s) for each g and every g' . The scattering for any g' not appearing in this table is zero. These data will be printed for every composition.

Page 100 again gives the geometry type and a set of coordinate axes. The variable defining the domain of the trial functions is always the vertical variable, the synthesis variable is always the horizontal one. This is followed by the values of the synthesis interface boundaries and the number of refined regions calculated by SYN2D. Next are printed the data-set reference numbers used by SYN2D for the two user-supplied trial-function libraries and the three module-generated trial-function libraries. If all the trial functions are held in core during the generation of these library data sets, a message to this effect is printed. Finally, the data-set reference number used to store the partial integrals and the actual time used by the module so far are printed.

Page 104 contains the maximum condition number over g for $D_g^k(x)$, which is computed for all values of mesh interval x and synthesis region k . The maximum is printed out for each energy group g . This is an attempt to check the linear independence of the trial functions. The exponent of the condition number is an indication of the ill-conditioning of the matrices. If the exponent is less than seven, the matrices are fairly well conditioned. The range seven to 13 indicates some degree of breakdown. Above 14, the matrices are definitely ill-conditioned. After the condition numbers are printed, all open data sets are rewound and the time required to calculate the finite-difference matrices is printed.

Pages 105-106 contain the iteration-monitoring information and indicate the data-set reference number on which the mixing functions are written out. The time spent in performing the iterations is also printed.

Page 107 contains the calculated mixing functions for the highest-energy group. The integers appearing under the heading 'X-AXIS' are the mesh intervals in which the mixing functions take on the indicated values. The mixing functions are defined at the center of each mesh interval. In each synthesis region, the integers appearing under the heading 'Y-AXIS' indicate which trial function each mixing function is associated with. When a different number of trial functions is used in each synthesis region, the mixing functions would be handled as follows: where for simplicity only two synthesis regions are assumed. Suppose that two trial functions are used in the first synthesis region, and three in the second. Then three mixing functions would be printed for each synthesis region, but the third mixing function in the first synthesis region would be identically zero. One page like this is printed for each energy group.

Page 108 contains the real trial functions for the highest-energy group for synthesis region one. The integers appearing under 'FNT NO' give the function number, each function corresponds to the mixing function in the same synthesis region with the same number as shown on page 107. One page like this is printed for each synthesis region and group.

Page 125 gives the data-set reference number on which the unnormalized, constituted two-dimensional flux was previously stored. This is followed by the message that the first record of ARC System data set FR D2 was written on the given data-set reference number.

Page 126 gives the total power in the reactor, the volume of each reactor region, the power in each region, and the average power of each region. The data-set reference number on which the ARC System data set FR.PN is written is followed by the burnup normalization factor and the message that the two-dimensional flux for the first energy group has been written.

Pages 127-128 are two of a number of pages giving the normalized two-dimensional flux for the highest-energy group. The last page of this flux printout indicates that the flux for the second-highest energy group has been written on ARC System data set FR.D2. One of these pages is printed for each energy group.

Pages 139-140 give the power per interval for the reactor. The maximum and minimum nonzero power and the coordinates at which these values occur is also printed.

Page 141 contains the flux volume by reactor region and energy group.

Page 142 contains the region-averaged real fluxes, normalized for burnup by reactor region and energy group.

Pages 143 through 148 show balance removal, scattering, fission source, and balance by region by reactor region and energy group.

Page 149 contains the on-averaged fission source summed by reactor region and energy group.

Page 149 contains balance removal, scattering, fission source absorption, external source, and balance by region summed over all energy groups, summed over all regions, and finally summed over the reactor. This is followed by the time required to calculate the reconstructed two-dimensional flux and perform the output edits. Then an open data set is closed and the total time spent in executing SYN2D is printed and execution is terminated.

The output described above is printed when the print flag is set to 1. When the print flag is set to 2, the magnitude and sign of the neutron currents across reactor region boundaries will be printed immediately preceding the normalized full-dimensional fluxes. Finally, when the print flag is set to 0, only the first normalized page, along with the data corresponding to that of pages 104, 108, and parts of pages 125, 126, and 149 will be printed. Hence, setting the print flag to 0 yields a very brief amount of output.

SYN2D(OLIB) Accelerator Program for Synthesis Trial-function Libraries

1. Introduction

The purpose of this program is to generate trial-function libraries FR TRIAL and FA TRIAL, which are input data sets to the synthesis module SYN2D (AC005). Since the record structure of both data sets is identical, only the construction of the real library (FR TRIAL) will be considered here, with comments applicable to FA TRIAL. To generate the real trial-function library, J2D(OLIB) accepts as input the two-dimensional flux FR D2, and one-dimensional flux FR D1. Great flexibility presents in the way that the input data sets may be combined to form the output data set; the user also exists of creating several output data sets during one run. Please notice that different types of input data sets may be combined.

2. Input Data Sets

Any combination of the following in any order is acceptable as input; any data set with the same record structure will also work.

a. FR D2 (FA D2)

b. FR D1 (FA D1)

2D record data specified below.

3. Output Data Sets

Any number of output data sets can be produced, each having the format of FR.TRIAL (FA.TRIAL).

4. Scratch Data Sets Used

J2DTOLIB requires GMAX scratch data sets, where GMAX is the number of energy groups.

5. Method of Operation

Figure 3 represents a typical two-dimensional XY reactor configuration with 20 intervals in each direction, with compositions c_1 , c_2 , c_3 , and c_4 assigned to the four reactor regions. (It is assumed that this problem has actually been run and that the resulting two-dimensional multigroup flux $F_g(x,y)$ has been put out on FR.D2.) To make a trial function from this flux, an x-direction interval number I_x is input, yielding the trial function $f_g(y) = F_g(x_{I_x}, y)$.

Fig. 3. Typical Two-dimensional XY Reactor Configuration

Trial functions may also be generated by indicating a y-direction interval number, J_y . The function then generated is $f_g(x) = F_g(x, y_{J_y})$. The one-dimensional data set FR.D1 is handled in the same fashion, except that in this case J2DTOLIB assumes that the two-dimensional map contains only one x-direction interval.

As many x-direction intervals as desired may be input, in any order and with duplications. J2DTOLIB will put the trial functions out on FR.TRIAL in the order in which they are specified. Note that for each x-direction interval indicated, there exists one $f_g(y)$ for each energy group. These are all picked and used to generate FR.TRIAL (i.e., if J2DTOLIB is given an input I_x , FR.TRIAL gets the set $\{f_g(y)\}_{g=1}^{GMAX}$). This is necessary because the trial functions used by SYN2D are group-dependent.

Previously, it has been noted that J2DTOLIB requires GMAX scratch data sets. This arises because of the incompatibility of FR.D2 and FR.TRIAL. Thus, each record of FR.TRIAL contains the set $\{f_g(y)\}_{g=1}^{GMAX}$, while each record of FR.D2 contains only one $f_g(y)$. These GMAX scratch data sets must be numbered consecutively, and must start with data-set reference number eight.

6. Input-card Specifications (J2D deck)

There are only four types of input cards to this program. All cards are set up with a structure of (16I5). Several input data sets can be used to create one output data set, however, only one output data set at a time can be created. The card types are listed below, and the structure of the deck is indicated in Section II.7.

Card Type One

Cols. 1-5 NUMCRD--Number of type-2 cards used. (Only one type-1 card is used per run.)

Card Type Two

Cols. 1-5 NQCARD--Number of type-3 cards used before next type-2 card.

Cols. 6-10 ICK--Creation option used.

0--Creates trial functions $f_g(y)$ from two-dimensional output

1--Creates trial functions $f_g(x)$ from two-dimensional output

2--Creates trial functions $f_g(y)$ from one-dimensional output

Card Type Three

Cols. 1-5 LIBRED--Data-set reference number for FR.D2 or FR.D1.

Cols. 6-10 LIBRIT--Data-set reference number for FR.TRIAL.

Cols. 11-15 LIBNUM--Number of trial functions chosen (limit 35).
When IC = 2, LIBNUM should be 1.

Card Type Four

(NUM(L), L=1, LIBNUM)--Function desired (indicated by interval numbers).
When I K = 2, NUM should be 1.

7. Sample Input

Following is a sample input which could be used to generate trial-function libraries. The input data-set types and data-set reference numbers are, respectively, FR.D2-1,3,4,13 and FR.D1-16,17,18. The output data sets (FR.TRIAL) are on data-set reference numbers 2 and 14. The two output data sets created could also be used as real and adjoint trial-function libraries. The card images and card types are listed below.

<u>Card Images</u>	<u>Card Types</u>
3	1
2 0	2
1 2 3	3
3 4 7	4
3 2 3	3
1 5 8	4
2 1	2
4 2 2	3
6 12	4
13 / 14 5	3
1 3 5 7 9	4
3 2	2
16 14 1	3
1	4
17 14 1	3
1	4
18 14 1	3
1	4

8. Printed Output: Messages and Significance

Below are listed all 12 messages J2DTOLIB can generate. Not all these messages will appear on a given run, so they are not necessarily listed by the order in which they will appear.

a. THE NUMBER OF OPTIONS USED IS nnnn

This should be the first printed message, where nnnn is NUMCRD from card type 1.

b. dddd DATA SETS WILL BE READ AND/OR WRITTEN WITH OPTION NUMBER pppp

This indicates that a block of type-3 and -4 cards follow; pppp is the option used for this block (ICK), and dddd indicates the number of type-3 cards (NOCARD). This message will appear for each type-2 card.

c. ATTEMPTING TO READ TOO MANY FUNCTIONS AT ONE TIME(nnnn)

After this message has been printed, execution is terminated; nnnn is the number of functions (L BNUM) that the program is trying to read following one type-3 card. Break the indicated type-3 and -4 cards into several sets until no more than 35 functions are referenced by each set. Change the preceding type-2 card to reflect this change.

d. DSRN READ IS rrrr DSRN WRITTEN IS wwww

NUMBER OF FUNCTIONS READ AND WRITTEN IS nnnn.

This message will appear for each type-3 card, where rrrr is LIBRED, wwww is LIBRIT and nnnn is LIBNUM.

e. FUNCTION NUMBERS r_1 r_2 r_3 ... r_{10}

This lists the function numbers on each type-4 card.

f. CONVERGED EIGENVALUE IS kkkk.

JMAX = jjj

IMAX = iii

GMAX = gggg

This gives some of the information read from the input data set; kkkk is the eigenvalue, and gggg is the number of energy groups. iii and jjj can take on various values, depending upon ICK. If ICK equals two, IMAX is one and JMAX is the number of mesh points for the one-dimensional problem. If ICK equals zero, IMAX is the number of x-direction mesh points and JMAX is the number of y-direction mesh points. If ICK equals 1, they are the reverse.

g. SPACE REQUIRED IS ssss SPACE AVAILABLE IS aaaa
ERROR

The problem requires more space than is available; execution is terminated. Presently aaaa is 20000. To run this problem, increase the size of array ARRAY and change the value of NUMBER in the data statement to correspond to the increase. (See program listing in Section II-9 below.)

h. MISSION ACCOMPLISHED.***

This signifies the successful completion of the job.

i. FLUX FOR GROUP gggg IS nnnn (1) FOR IN (2) FOR OUT

This message appears twice per group when ICK equals zero or one and signifies that we are dealing with the two-dimensional flux for group gggg. When nnnn equals one, we have successfully read in this flux. When nnnn equals two, the desired trial functions have been temporarily written out on the scratch data set. If ICK equals two, this message will appear once per group only, when nnnn equals two.

j. THERE WILL BE nnnn FUNCTIONS ON DSRN dddd

DATA SETS HAVE BEEN REWOUND AND ARE BEING READ.

This message appears just before the generation of FR TRIAL on data-set reference number dddd, nnnn is the total number of trial functions to be put on this data set.

k. FUNCTION NUMBER mmmm HAS BEEN WRITTEN OUT

This message appears after each function mmmm has been printed out and written on data-set reference number dddd (message j).

l. INTERVAL iii DOES NOT EXIST. THEREFORE NO TRIAL FUNCTION CAN BE GENERATED.

This message appears when iii exceeds the value of IMAX. No interval corresponds to this value; hence, no valid trial function can be generated. J2DTOLIB will, however, attempt to write a function and, if successful, will continue execution.

9. JCL and Program Listings

Following is a sample job-control language deck for executing this program. Here, FR.D2 is on data-set reference number 1, FR.TRIAL is on data-set reference number 16, and the GMAX scratch data sets begin at data-set reference number 8. Below the job deck is a listing of the program.

```
//JOB CARD
  ACCOUNTING CARD
  /*SETUP DDNAME=DUMMY,DEVICE=2314,LD=DISKLL
  //LIBGEN EXEC PROC=FTHCLG
  //FTH.SYSIN DD *
    CARD DECK TO BE COMPILED (J2D-OLIB DECK)
  /*
  //GD.FT01F001 DD DSN=GE,CBRT ,DISP=(OLD,KEEP),UNIT=DISK,
  //GD.FT01F001 DD UNIT=2314,VOL= ER=DISKLL,DISP=(OLD,KEEP),DSN=FR.D2
  //FT08F001 DD UNIT=DISK,SPACE=( L,(1,1)),VOLUME=SER=SCRONE,
  //          DCB=(RECFM=VB,LR L=256,BLKSIZE=7172)
  //          OTHER SCRATCH DATA SETS WHICH ARE REQUIRED
  //GD.FT16F001 DD DSN=FR.TRIAL,DISP=(NEW,KEEP),VOL=SER=DISKLL,UNIT=2314,
  //          SPACE=(CYL,(1,1)),DCB=(RECFM=VB,LRECL=256,BLKSIZE=7172)
  //GD.SYSIN DD *
  J2DTOLIB BCD CARD DECK
```

```

C
C PROGRAM J2D7OL18
C
C IMPLICIT REAL*8(A-H,O-Z)
C DIMENSION ARRAY(20000)
C DATA NUMBER/20000/
C COMMON/INFO/NINT1,NINTJ,NGROUP,LIBRED,LIBRIT,NDFUNT,NUM(50),ICK,
C LIBNUM,NSPACE,IDSRN(30)
C
C NUMCRD=NUMBER OF CARDS CONTAINING NDCARD&ICK.
C NUCARD=NUMBER OF CARDS CONTAINING LIBRED WHICH FOLLOW.
C ICK - CREATION OPTION.
C 0-READS 2-DFLUXES FROM DSRN LIBRED AND TAKES FLUXES FOR INTERVAL
C POINTS J AND ALL GROUPS G & PUTS THEM OUT AS 1 RECORD ON
C DSRN LIBRIT. DIFFERENT LIBRED'S CAN BE PUT OUT ON ONE LIBRIT.
C 1-SAME AS OPTION 0 EXCEPT IT FLIPS THE RECORDS OF FR,02
C TO GENERATE TRIAL FUNCTIONS FROM HORIZONTAL PROFILES IN
C STEAD OF VERTICAL ONES.
C 2-READS THE OUTPUT FROM A 1-DIMENSIONAL JOB AND PUTS IT
C IN PROPER FORM SO THAT IT CAN MIX WITH OTHER FUNCTIONS
C AND OTHER OPTIONS.
C LIBRED=DSRN WHERE FLUXES ARE TAKEN FROM.
C LIBRIT=DSRN WHERE TRIAL FUNCTIONS ARE STORED.
C LIBNUM=NUMBER OF FUNCTIONS TAKEN FROM LIBRED TO PUT ON LIBRIT.
C NUM -FUNCTIONS FROM INTERVALS NUMBERED BY NUM.
C *****LIMITS**NUM(50),6 GROUPS OR LESS.
C *****LIMITS**IDSRN(30)
C EXAMPLE CARDS INDICATES 1 NUCARD FOLLOWS.
C 1
C EXAMPLE CARD1 INDICATES 2 DATA SET CARDS WITH 0 OPTION.
C 2 0
C CARD2, READING FROM FTO3 & WRITING ON FTO4 TWO FUNCTIONS.
C 3 4 2
C CARD3 GIVES INTERVAL NUMBERS.
C 1 5
C CARD4, READING FROM FTO5 & WRITING ON FTO4 TWO FUNCTIONS.
C 5 4 2
C CARD5 GIVES INTERVAL NUMBERS.
C 2 3
C DO 9 I=1,30
C 9 IDSRN(I)=1+7
C NDFUNT=0
C READ(5,2) NUMCRD
C PRINT 25,NUMCRD
C DO 13 I=1,NUMCRD
C READ(5,2) NDCARD,ICK
C PRINT 26,NDCARD,ICK
C DO 10 I=1,NDCARD
C READ(5,2) LIBRED,LIBRIT,LIBNUM
C IF(LIBNUM.LT.51) GO TO 36
C PRINT 27,LIBNUM
C STOP
C 36 READ(5,2) (NUM(J),J=1,LIBNUM)
C REWIND LIBRED
C IF(ICK.EQ.2) READ(LIBRED) NINTJ,NGROUP,EVALUE
C IF(ICK.EQ.0).OR.(ICK.EQ.1) READ(LIBRED) NINT1,NINTJ,NGROUP,EVALUE
C IF(ICK.EQ.2) NINT1=1
C IF(ICK.EQ.0).OR.(ICK.EQ.2) GO TO 20
C NDT=NINT1
C NINT1=NINTJ

```

```

      NINTJ=NOT
20 IF(NOFUNT.NE.0) GO TO 24
      LIB=LIBRIT
24 IF(LIBRIT.EQ.LIB) GO TO 23
      LIB=LIBRIT
      CALL RITFLX
      NOFUNT=0
      DO 18 J=1,NGROUP
        NJT=IDSRN(J)
        REWIND NOT
18 CONTINUE
23 NOFUNT=NOFUNT+LIBNUM
17 PRINT 7,LIBRED,LIBRIT,LIBNUM
      PRINT 8,(NUM(J),J=1,LIBNUM)
      PRINT 1,EVALUE,NINTJ,NINTI,NGROUP
      NSPACE=NINTJ*MAXO(NINTI,NGROUP)
      IF(NSPACE.GT.NUMBER) GO TO 70
      CALL READFLX(ARRAY)
10 CONTINUE
13 CONTINUE
      CALL RITFLX
      DO 5 I=1,NGROUP
        NOT=IDSRN(I)
        REWIND NOT
5 CONTINUE
100 PRINT 111
      STOP
70 PRINT 3,NSPACE,NUMBER
1 FORMAT(' CONVERGE' EIGENVALUE IS ',020,10//', JMAX= ',14//',
1 IMAX= ',14//', GMAX= ',14)
2 FORMAT(16,15)
3 FORMAT(' SPACE REQUIRED IS ',16,' SPACE AVAILABLE IS ',16,' ERROR')
7 FORMAT(//,//,/)
1 DSRN READ IS ',15,' DSRN WRITTEN IS ',15,' NUMBER OF FUNC-
TIONS READ AND WRITTEN IS ',15)
8 FORMAT(' FUNCTION NUMBERS ',16,15)
25 FORMAT(' THE NUMBER OF OPTIONS USED IS ',15)
26 FORMAT(' ',15,15)
1 ' ',15,' DATA SETS WILL BE READ AND/OR WRITTEN WITH OPTION
1 NUMBER ',15)
27 FORMAT(//,//,/) ATTEMPTING TO READ TOO MANY FUNCTIONS AT ONE TIME('
1 ',14,15)
111 FORMAT(' MISSION ACCOMPLISHED.***')
      STOP
      END
      SUBROUTINE READFLX(FLUX)
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON/INFO/NINTI,NINTJ,NGROUP,LIBRED,LIBRIT,NOFUNT,NUM(50),ICK,
1 LIBNUM,NSPACE,IDSRN(30)
      DIMENSION FLUX(NINTJ,NINTI)
      DATA IONE/1/,ITWO/2/
      MLIB=LIBRIT
      NLIB=LIBRED
      IF(ICK.EQ.2) GO TO 17
      DO 7 LG=1,NGROUP
        IF(ICK.EQ.0) READ(NLIB) ((FLUX(J,I),I=1,NINTI),J=1,NINTJ)
        IF(ICK.EQ.1) READ(NLIB) ((FLUX(I,J),I=1,NINTJ),J=1,NINTI)
        PRINT 20, LG, IONE
        NOT=IDSRN(LG)
        DO 10 I=1,LIBNUM

```

```

      IF (NUM(I),GT,NINTJ) PRINT 24,NUM(I)
      WRITE(NTJ,1)FLUX(J,NUM(I)),J=1,NINTJ)
10  CONTINUE
      PRINT 20 ,LG,ITWO
      CONTINUE
      REWIND MLIB
      RETURN
17  CONTINUE
      READ(MLIB,1) (FLUX(J,I),J=1,NINTJ),I=1,NGROUP)
      DO 19 LG=1,NGROUP
        NUT=IDSRN(LG)
        WRITE(NTJ,1)FLUX(J,LG),J=1,NINTJ)
        PRINT 20 ,LG,ITWO
19  CONTINUE
      REWIND MLIB
      RETURN
      ENTRY RITFLX
21  DO 16 NG=1,NGROUP
      NUT=IDSRN(NG)
      REWIND NTJ
16  CONTINUE
      PRINT 18,NOFUNT,MLIB
      PRINT 21
50  CONTINUE
      WRITE(MLIB ,1)NOFUNT,NINTJ,NGROUP
      DO 5 I=1,NOFUNT
        DO 13 LG=1,NGROUP
          NUT=IDSRN(LG)
          READ(NTJ,1)FLUX(J,LG),J=1,NINTJ)
11  PRINT 6, (FLUX(J,LG),J=1,NINTJ)
13  CONTINUE
          WRITE(MLIB ,1)((FLUX(J,L),J=1,NINTJ),L=1,NGROUP)
          PRINT 23,I
5  CONTINUE
      REWIND MLIB
6  FORMAT(' ',6D20.10,/)
18  FORMAT(' THERE WILL BE ',I5,' FUNCTIONS ON DSRN ',I3)
20  FORMAT(' FLUX FOR GROUP ',I3,' IS ',I3,' (1) FOR IN (2) FOR OUT.')
21  FORMAT(' DATA SETS HAVE BEEN REWOUND AND ARE BEING READ.',/,I3)
23  FORMAT(' FUNCTION NUMBER ',I3,' HAS BEEN WRITTEN OUT.',/,/)
24  FORMAT(' INTERVAL ',I3,' DOES NOT EXIT, THEREFORE NO TRIAL FUNCTIO
IN CAN BE GENERATED.')
      RETURN
      END

```


Subroutines contained in each SYN2D segment

<u>SYN2D</u>	<u>SYNDIF2D*</u>	<u>SYNNB</u>	<u>SYNNC</u>
Modul. SYN2D	FRRMSG	SYNN	LIB
CLOSE	PAGHEL	RQDFP	FPRIME
	IVOL	RSDEF	PROCES
	IAREA	STOFF	RIEMAN
	PGEOM	ALC	VALUES
	GETBND		DSRNCK
	PCOMP		
<u>SYNRB*</u>	<u>SYNRG*</u>	<u>SYNRC*</u>	<u>SYNMSC</u>
RBNCD	RGEOM	RCOMP	D2DCAL
STORBC	RMESH	RXSCOI	MINV (IBM SSP routine)
PRIBC		RGROUP	GMPRD (IBM SSP routine)
		GETCHI	MOVE
		DIMSCT	MADD
		PCKSCT	NUMMLT
		RVEL	MSUB
		RDELAY	
		RKN	
<u>SYNGENB</u>	<u>SYNGENC</u>	<u>SYNGEND</u>	<u>SYNCALB</u>
COGEN	MTGEN1	SYNGEN	SYNCAL
BONDS	CALC1	CHECK	SINCAL
	CALC2	MTGEN2	SWEEP1
		NORM	SWEEP2
<u>SYNOUTB</u>	<u>SYNOUTC*</u>	<u>SYNOUTD*</u>	<u>SYNOUTE*</u>
SYNOUT	D2DOU1	IFXNRM	ILKCEL
SINOUT	IFXVOL	IGPCAL	FLUXPR
		IRG AL	
<u>SYNOUTF*</u>			
ITOBAL			
FLOP			
TWODPR			

The segments marked with an asteris (*) contain subroutines also used by the two-dimensional diffusion module.

2. Description of Program Structure and Flow

Module SYN2D is entered by execution of a LINK command in a path. Its first call is to TLEFT (IBM routine) to obtain the amount of computer time remaining before execution of the module is terminated.

Then CLOSE is called to rewind any open data sets. Next, SYN2D calls subroutine SYNIN, which controls the reading of all data sets needed for execution and creates the preprocess data sets.

SYNIN first calls TLEFT, and then calls RCODEP to read module-dependent data from data set A.SYN2D. The first five records are read, the first two being ignored since they are set up by BCDDS¹ to describe the data set structure. Variables used by the two-dimensional diffusion capability, which shares some of these subroutines, are set to the appropriate values for a real, homogenous k-effective calculation. POINTR¹ is initialized, and if bulk core has been requested, a call to entry BULK of POINTR is made. Calls to SNIFF¹ are made to get the data-set reference numbers for A.SYN2D and the four scratch data sets used by the module.

SYNIN next calls RGEOM, which controls reading of all geometry data from data set GEOM. SNIFF is called to obtain the data-set reference number for GEOM. The first record is read, and storage is allocated; then RMESH is called, and the remaining records of GEOM are read. RGEOM then initializes functions IVOL and IAREA, and if a print of geometry data is requested, PGEOM is called.

SYNIN then calls RCOMP to read in the composition data. SNIFF is called to get the data-set reference number for XS C MIN. Storage is then allocated and RXSCOL is called to read in the composition names from the first record of SX C MIN. RCOMP then calls GETCHI to read the next record if there is a set-wide fission spectrum. RDELAY is not called, since this module has no kinetics option. RGROUP is then called once for each composition, to read the group-dependent XS C MIN data. RCOMP next calls DIMSCT to set up the position of the scattering terms in the scattering array, PKSGT to pack the scattering array by compositions, and, if requested, PCOMP to print the composition-related data. RCOMP's final call is to RVEL to set up dummy neutron speeds by group, which are not used by synthesis.

SYNIN next calls RBNDG, which controls the reading of the boundary-condition data from data set BC. Storage is allocated; and a call to SNIFF is made to obtain the data-set reference number for BC. BC is read in RBNDG; the data are stored in an array by STORBC and, if requested, are printed out by PRTEBC.

SYNIN then calls RSDEF, which checks the geometry type, reads the next record (type 04 card) of data set A.SYN2D, allocates storage, and then calls SYNDEF to read the types 05, 06A, 06B, and 06C cards from data set A.SYN2D. These cards define the synthesis-region boundaries and the trial functions that will be used by this problem. RSDEF then calls RRCALC

¹ARC system utility subroutine

to determine the X-direction refined region boundaries for the entire reactor and the Y-direction refined interval boundaries for each synthesis region. RSDEF next makes several calls to SNIFF to obtain the data-set reference numbers for the data sets LIB.REAL, LIB.ADJT, and LIB.MIX. If these data sets have not been previously written, a call to LIB is made. LIB calls SNIFF to obtain the data-set reference numbers for LIB.REAL, LIB.ADJT, LIB.MIX, FR.TRIAL, and FA.TRIAL. The three problem-dependent trial-function libraries are then created by LIB. If all the real trial functions required cannot be held in core at one time, the last record of A.SYNED is read to indicate which scratch data sets should be used in the trial-function library generation. When the three data sets are old, LIB is not called.

RSDEF then calls SNIFF for the data-set reference number of LIB.PART. If this data set has not been written, RSDEF calls PROCES to generate the partial integrals. PROCES first calls SNIFF to obtain the data-set reference number for LIB.PART and then calls DSRNCK, which checks to see if the data sets LIB.REAL, LIB.ADJT, and LIB.MIX are consistent with each other and with the specifications for this problem. PROCES then calculates the partial integrals, using RIEMAN to perform the actual integration, FPRIME to differentiate the trial functions, and VALUES to calculate the values for each trial function at the reactor boundaries. These three subroutines are called repetitively, with RIEMAN and VALUES writing the records of LIB.PART just before each return to PROCES. Finally PROCES calls CLOSE to rewind the data sets.

If LIB.PART is old, no call to PROCES is made. If neither LIB nor PROCES was called by RSDEF, a call to DSRNCK is made. Finally, RSDEF calls CLOSE.

Following the call to RSDEF, SYNIN calls TLEFT and prints the time required for the execution of the subroutine SYNIN. Control is then returned to SYNED. For a preprocessing run, execution is terminated here.

SYNED next calls D2DCAL, which is not a two-dimensional diffusion subroutine. D2DCAL calls SYNGEN, which is the driver for the generation of the coefficient matrices.

SYNGEN first calls TLEFT and then calls SNIFF to obtain the data-set reference number for data set XSCMIN. Array storage is then allocated and CHECK is called to generate the interval-to-synthesis-region correspondence. Next SYNGEN initializes COFGEN, MTGEN1, and MTGEN2 and then calls entry COFF1 of COFGEN once for each group. COFGEN calculates all the coefficient matrices $[D_{gk}(r)]$, $[L_{gk}(r)]$, $[E_{gk}(r)]$, $[E_{g,k}(r)]$, $[(x_{g,g} \cdot E_{fg})_k(r)]$, $[W_{gk}]$, $[A_g^k]$, $[B_g^{(k+1)}]$, $[B_g^k]$, and $[B_g^{(k+1)}]$, calling BCONDS to

calculate $[G_{gk}(r)]$. These matrices are calculated from the partial integrals generated previously. Calls to GETBND entries VERBND and HORBND by COFGEN and BCONDS are made to obtain the boundary conditions applied at the reactor left and right boundaries and top and bottom boundaries, respectively. COFGEN writes the fission matrices $\{[(\chi_{gv}, \Sigma_{fg})_k(r)]\}$ and the scattering matrices $\{[\Sigma'_{g'g,k}(r)]\}$ on scratch data sets SCR002 and SCR004, respectively. After the call to COFGEN, SYNGEN calls entry MTGEN1 of MTGEN1, which is the driver for the generation of the matrices $\{H_i\}$, $\{G_i\}$, and $\{E_i\}$. First MTGEN1 calls CALC1 to generate D_i^{-1} , then CALC2 is called to calculate E_i , G_i , and H_i . (Note that E_{iMAX} and part of E_i are computed in MTGEN1.) The norm of $[D_{gk}(r)]$ is also approximated by MTGEN1, and the largest norm is printed out.

Next SYNGEN calls MTGEN2 (entry MTGN2), which computes the matrices $\{U_i^{-1}\}$, $\{V_i\}$, and $\{H_i\}$ from $\{E_i\}$, $\{G_i\}$, and $\{H_i\}$ and writes $\{U_i^{-1}\}$ and $\{V_i\}$ on scratch data set SCR003 and $\{H_i\}$ on scratch data set SCR001. Finally, after COFGEN, MTGEN1, and MTGEN2 have been called once for each group, SYNGEN calls CLOSE and TLEFT and prints out the time required for the execution of SYNGEN.

D2DCAL next calls SYNCAL, which calls TLEFT, allocates array storage, and then calls SINCAL. SINCAL first initializes SWEEP1 and SWEEP2 and then performs the required power iterations necessary for the problem's solution. After each outer iteration, monitoring information is printed out. SWEEP1 performs the forward sweep of the Choleski method, while SWEEP2 performs the backward sweep. SINCAL returns control to SYNCAL when the power iterations have converged, the maximum number of iterations has been exceeded, less than 30 sec of computer time remains, or a program-detectable error has been encountered. SNIFF is called by SINCAL to obtain the data-set reference number for FR.TG, which is written before control is returned to SYNCAL. Finally, SYNCAL calls TLEFT and prints the time required for the execution of SYNCAL.

After the call to SYNCAL, D2DCAL returns control to module SYN2D. SYN2D then calls SYNOUT, which in turn calls TLEFT, allocates storage, and then calls SINOUT to calculate the final reconstructed two-dimensional fluxes from the mixing functions calculated in SINCAL and the user-supplied real trial functions.

SINOUT calls TWQDP to print out the mixing functions and, if requested, the real trial functions. SINOUT writes the unnormalized two-dimensional fluxes on SCR001 for later use by D2DOUT. After calculation of the two-dimensional fluxes for all energy groups, SINOUT returns control to SYNOUT, which then calls D2DOUT, which is the two-dimensional diffusion-output edit driver. SINOUT allocates storage and then initializes IFXVOL, IFXNRM, IGRCAL, IRGBAL, GETBND, ILKCEL, and ITOBAL. Then entry

FXVOL of IFXVOL is called by D2DOUT to calculate the regional flux integrals for all groups. IFXVOL then calls entry VOL of IVOL to help calculate the region volumes.

D2DOUT then calls entry FLXNRM of IFXNRM, which calculates the power-normalization factor for burnup and then normalizes regional flux integrals and region-averaged fluxes for data set FR.PN. FLXNRM also calculates total power, power, and average power by region. The data-set reference number for FR.PN is obtained by a call to SNIFF.

D2DOUT next calls entry of IGPCAL, which normalizes the two-dimensional fluxes for all groups to one fission in the reactor and accumulates the power density by mesh point. SNIFF is called to obtain the data-set reference number for FR.DZ, which is then written out. If desired, entry REGBAL of IRGBAL is then called by GPCAL.

REGBAL calls entry LKCELL of ILKCEL, which calculates the total leakage out of a cell and the neutron currents across each interface of the cell. Using this information, REGBAL calculates the contribution to the total balance by region and group, including leakage, removal, scattering, and fission. It also calculates and prints neutron currents across region boundaries if desired.

D2DOUT then, if requested, calls FLUXPR to print out the two-dimensional fluxes and power. Next, if desired, entry TOTBAL of ITOBAL is called by D2DOUT.

ITOBAL calculates the following arrays by region and group: flux integrals, averaged flux integrals, leakage, removal contribution to balance, scattering source contribution, fission-source integrals, output balance sums, average fission-source integrals, and source volume integrals. These arrays are then printed out. The arrays are next summed over all groups for each region and printed out. Then they are summed over all regions for each group and printed out. Finally each array is summed over both region and group and printed out.

TWQDPR is called in each case to print out the arrays.

After the call to TOTBAL, D2DOUT returns control to SYNOUT. (FLOP is never called, since the problem type is never adjoint.) SYNOUT then calls TLEFT and prints the time required for the execution of SYNOUT, after which control is returned to SYN2D.

SYN2D then calls FREE to release the storage held by the container array. A TLEFT call is made, and the total time required to execute the SYN2D module is printed out. Then control is returned to the calling path.

Figure 4 is a diagrammatic subroutine calling map. This map contains no logic and is only intended to show the subroutine calling hierarchy. Entry-point references have been indicated only when the main calling sequence is not called in the same subroutine as the entry point.

B. Common-block Descriptions

This section provides detailed information about the common blocks used by the SYN2D subroutines. The common blocks appear in alphabetical order by name.

For each common block, all variables are listed in order of appearance in the block by name and type, and each is defined. If a variable is dimensioned, the dimension follows the variable name in parentheses. In addition, there appears for each variable a list of the subroutines in which the value of the variable is set (S) or modified (M).

A special case is the BLKSTR common block, which contains the container array BLK used by the dynamic storage allocation module POINTR (see ANL-7711¹). Section C contains a list of all names of all arrays that may be defined in the container array at any point in the execution of the module.

For the SINGLE common block, which contains the single variables used by the program, the local name of each variable is given, followed by its location in the FLT or INT array, the subroutines where its value is set or modified, and its definition.

I. BCBLK

<u>Name</u>	<u>Type</u>	<u>Subroutines Where Values Are Set or Modified</u>	<u>Definition</u>
MSHTYP	R*4	M-RBND	Alphanumeric data, printed to indicate whether mesh line at which boundary condition applies is horizontal or vertical ('HOR' or 'VER,' respectively).
MESH	I*4	M-RBND	Mesh-line number and side indicator to which this record refers. For a vertical interface, - sign is left side of line, + sign is right side of line. or a horizontal interface, + sign is top side of line, - sign is bottom side of line.

Name	Type	Subroutines Where Values Are Set or Modified		Definition
MESH1	I*4	M-RBND	C	The mesh-line number defining the beginning of the boundary-condition interval along this interface
MESH2	I*4	M-RBND	C	The mesh-line number defining the end of the boundary-condition interval along this interface
GINT	I*4	M-RBND	C	The initial high-energy group number to which this set of constants applies.
GFIN	I*4	M-RBND	C	The final lower-energy group number to which this set of constants applies.
ITYPE	I*4	M-RBND	C	The type of boundary condition. ITYPE = 1, $C_1\phi' + C_2\phi = C_3$, ITYPE = 2, $C_1D\phi' + C_2\phi = C_3D$, where D is the diffusion coefficient
C(4)	R*4	M-RBND	C	The boundary-condition constants C_1 , C_2 , and C_3 , referred to by ITYPE. (C_4 is not used at present.)

2. BLKSTR

Name	Type	Subroutines Where Values Are Set or Modified		Definition
BLK(1)	R*8	S-RCDEF	C	This array, whose size is defined at execution time, is used as the container array for the dynamic storage array allocation program, POINTR.

3. HEADER

Name	Type	Subroutines Where Values are Set or Modified		Definition
TITLE(10)	R*8	S-RCDEF	C	Page heading (10A6), from data set A.SYN2D.

<u>Name</u>	<u>Type</u>	<u>Subroutines Where Values Are Set or Modified</u>		<u>Definition</u>
NPAGE	I*4	S-RCDEP	M-PAGED	Page number, initialized at zero and incremented with each printing

4 NAMBLK

<u>Name</u>	<u>Type</u>	<u>Subroutines Where Values Are Set or Modified</u>		<u>Definition</u>
NAME	R*8	S-ERRMSG		Name of subroutine calling ERRMSG (A8)

5. SINGLE

<u>Name</u>	<u>Type</u>	<u>Definition</u>
FLT(100)	R*8	100 floating-point single variables, described below
INT(200)	I*4	200 integer single variables, described below

<u>Name</u>	<u>Position in FLT Array</u>	<u>Subroutines Where Values Are Set or Modified</u>		<u>Definition</u>
PROB	1	S-RCDEP		Problem type, set to 'REAL' for use by the two-dimensional diffusion subroutines.
{KEFF LAMDA}	2	S-SINC L		Computed k-effective for problem.
ALPHA	3	S-RCD P		Inverse reactor time period α (set to 0 for use by the two-dimensional diffusion subroutines).
PROBT	5	S-RCD P		Calculation type, set to 'KCALC' for use by the two-dimensional diffusion subroutines.
MU	6	Not set		$\mu = 1/k_{\text{fixed}}$ (used only in two-dimensional diffusion-source calculations).

<u>Name</u>	<u>Position in FLT Array</u>	<u>Subroutines Where Values Are Set or Modified</u>	<u>Definition</u>
EPOELX	11	S-RCDEP	Flux-difference convergence criterion for outer iterations, ϵ_ϕ . $\epsilon_\phi \geq \sum_{gin} 1 - \phi_{gin}^{(l-1)} / \phi_{gin}^{(l)} $
EPSLAM	12	S-RCDEP	Flux-bounds-difference convergence criterion for outer iterations, ϵ_λ . $\epsilon_\lambda \geq (\lambda_{UP}^l - \lambda_{DN}^l)$ where $\lambda_{UP}^l = \max_{gin} (W_{gin}^l)$ $\lambda_{DN}^l = \min_{gin} (W_{gin}^l)$ and $W_{gin}^l = \phi_{gin}^{(l)} / \phi_{gin}^{(l-1)} $
EPSKEF	13	S-RCDEP	k-effective convergence criterion, ϵ_k . $\epsilon_k \geq v^l - v^{(l-1)} $ where v^l is the l th eigenvalue approximation.
GEOM	31	S-RGEOM	Geometry type: XY, RX, XR, or RT.
XL	32	S-RMESH	Left reactor boundary.
XR	33	S-RMESH	Right reactor boundary.
YB	34	S-R H	Bottom reactor boundary.
YT	35	S-R H	Top reactor boundary.
POWIN	71	S-RCD P	Burnup calculation power normalization factor. If user input is 0.0 or blank, POWIN is set to 1.0.

<u>Name</u>	<u>Position in INT Array</u>	<u>Subroutines Where Values Are Set or Modified</u>	<u>Definition</u>
MKRTHY	1	S-RCDE	Problem type, set to 0 for use by two-dimensional diffusion subroutines.

Name	Position in INT Array	Subroutine Where Value Are Set or Modified	Definition
KINOPI	2	S-RCDEP	Kinetic option, set to 0 since SYN2D has no kinetic capability.
MAXSIZ	4	S-RCDEP	Maximum size of the variable-dimensional main storage array BLK which is used by POINIR (default 99999).
IPRINT	5	S-RCDEP	POINIR debugging print flag. 0 No print. 1 POINIR trace prints. 2 POINIR dumps. 3 Both dumps and trace prints.
KORDER	6	S-RCDEP	
KOUT	7	S-RCDEP	Printed output flag. 0 Problem specifications and iteration history only. 1 Above, plus balance calculations. 2 Above, plus power calculations.
NMAX	11	S-RCDEP	Maximum number of outer iterations.
MXBULK	19	S-RCDEP	Size of the variable-dimensional bulk core array BLK which is used by POINIR (default 120000).
IRTPER	30	S-IVOL	RG geometry periodic flag, set to 0 for use by two-dimensional diffusion subroutines.
RMAX	31	S-RGEOM	Number of reactor regions.
IMAX	32	S-RGEOM	Number of X-direction mesh intervals.
JMAX	33	S-RGEOM	Number of Y-direction mesh intervals.
NBCDEF	34	S-RBNDC	Number of boundaries with boundary conditions (should always be 4).
CMAX	35	S-RCOMP	Number of compositions.
FSCMAX	36	S-RCOMP	Number of fissionable compositions.
GMAX	37	S-RCOMP	Number of energy groups.
GMAXUP	38	S-RCOMP M-RGROUP	Number of upscatter groups.

Name	Position in INT Array	Subroutine Where Value Are Set or Modified	Definition
MTRCH	39	S-RCOMP	X-matrix flag (always set to 1, since only X vectors are allowed).
CHIDIM	10	S-RCOMP	First dimension of X array (CH(CHIDIM, GMAX), where CHIDIM = FSCMAX*GMAX**MTRCH).
SCTDIM	41	S-RCOMP	First dimension of packed scattering array (SCTXS(SCTDIM, GMAX)) where $SCTDIM = \sum_{C=1}^{GMAX} [SCTLIM(1, C) + SCTLIM(2, C) + 1].$
NFAM	44	S-RCOMP	Number of delayed families (should be 0).
MAXUP	46	S-RGROUP M-COGEN	Maximum upscattering over all compositions, $\max_C [SCTLIM(2, C)]$ (should be 0).
MAXDN	47	S-RGROUP	Maximum downscattering over all compositions, $\max_C [SCTLIM(1, C)]$.
NBLACK	50	S-RCDEP	Number of black compositions (set to 0).
{NLIB NTH}	51	S-RCDEP	Scratch data-set reference number for SCR001 (see Section III.E).
{ILIB IFISS}	52	S-RCDEP	Scratch data-set reference number for SCR002 (see Section III.E).
JLIB	53	S-RCDEP	Scratch data-set reference number for SCR003 (see Section III.E).
KLIB	54	S-RCDEP	Scratch data-set reference number (presently 94, but not now in use).
LLIB	55	S-RCDEP	Scratch data-set reference number (presently 95, but not now in use).
{MLIB ISCAT}	56	S-RCDEP	Scratch data-set reference number for SCR004 (see Section III.E).

Name	Position in INT Array	Subroutines Where Values Are Set or Modified	Definition
ITERNO	57	S-SINCAL	Number of outer iterations used
IPROB	53	S-RCDEF	Calculation type, set to 0 for use by two-dimensional diffusion modules.
KFLAG	94	S-RCDEF	Search flag for type of variable prescribed, set to 0 for use by two-dimensional diffusion modules. (SYN2D has no search capability)
{N NINPUT}	101	S-RCDEF	Data-set reference number for data set A SYN2D.
KMAX	102	S-RSDEF	Number of synthesis regions
NGKMX	103	S-SYNDEF	Maximum number of real trial functions per synthesis region over all regions and all groups.
NGKPMX	104	S-RSDEF	Identical to NGKMX above. NGKPMX remains from an earlier version of the code.
NALPHA	105	S-RSDEF	Indicates, along with NBETA the weight function to use when generating the coefficient matrices. 1. for RZ geometry. 0. for XY and ZR geometry.
RRMAX	106	S-RRCALC	Number of refined regions.
NBETA	107	S-RSDEF	See NALPHA. 1. for XY geometry. 0. for RZ and ZR geometry.
IADJT	108	S-RCDEF	Adjoint trial-function flag. 1. Real trial functions should be used as adjoints also. 0. User will supply adjoint trial functions.
N1	110	S-RSDEF	Data-set reference number for data set LIB-REAL
N2	111	S-RSDEF	Data-set reference number for data set LIB-ADJT
N3	112	S-RSDEF	Data-set reference number for data set LIB-MIX.

<u>Name</u>	<u>Position in INT Array</u>	<u>Subroutines Where Values Are Set or Modified</u>	<u>Definition</u>
LPART	113	S-RSDEF S-PROCES	Data-set reference number for data set LIB.PART.
TIMEKY	115	S-DSRNCK S-LIB	Time key which is put on LIB.ADJT, LIB.MIX, LIB.PART, and LIB.REAL to give a key for identification. Indicates if the data sets are consistent, i.e. were created on the same problem run.
IOPT	117	S-RCDEP	Interface option flag. 1. Use asymmetric interface condition 2. Use symmetric interface condition.
KOPT	118	S-RSDEF	Preprocess option. 1 Preprocess only. 0: Run entire problem.

C. Dynamic Storage Array Allocation

This section describes all arrays which may be defined by this module in common block /BLKSTR/BLK, using the facilities of the dynamic storage allocation module POINTR (see ANL-7711¹). The arrays are listed in alphabetical order of the name given them in the POINTR name table.

The following information is given for each array.

1. Type.
2. Dimension, in terms of module variables.
3. Names of subroutines here action is taken that affects the status of the array in the container, followed in parentheses by the action taken in the subroutine. (Here, significant INTR calls are generally PUTPNT, which allocates space in the container for the array; REDEF, which sets aside space if the array is not present or redefines its space allocation if it is; and WIPOUT, which removes the array from the name table, thus making it inaccessible. The meaning of any other POINTR calls listed can be found in the POINTR documentation.)
4. Names of subroutines in which the value of elements of the array are set (S) or modified (M).
5. The definition of the array contents.

If the meaning of a variable used as the dimension of an array is not known, it can be found in the subroutine in which a call to PUTPNT or REDEF is made for that array.

Name	Type	Dimension	Subroutines Issuing Significant POINTR Calls	Subroutines Where Values Are Set or Modified	Definition
AMN	R*8	(NGKMX,NGKMX, KMAX-1)	SYNGEN(PUTPNT) SYNGEN(WIPOUT)	M-COFGEN	A _{gk} for all groups g and all required synthesis regions k
AREA	R*8	(NGKMX,NGKMX)	SYNGEN(PUTPNT) SYNCAL(WIPOUT)	M-CALC1 M-CALC2 M-COFGEN M-SWEEP1 M-SWEEP2	Temporary matrix storage array
BLKCMP	R*8	(NBLACK)	RCDEP(PUTPNT)	Not set or modified	Names of compositions de- fined as black compositions, used only by two- dimensional diffusion sub- routines (NBLACK is set to 0 in RCDEP)
BLKGRP	I*4	(NBLACK,2)	RCDEP(PUTPNT)	Not set or modified	Numbers of initial and final energy groups between which a composition named in BLKCMP is defined as being black. For a compo- sition BLKCMR(N), BLKGRP(N,1) is the initial energy group, and BLKGRP(N,2) is the final energy group. If BLKGRP(N,1) = 0, the con- dition is applied over all energy groups in the compo- sition. If BLKGRP(N,2) = 0 and BLKGRP(N,1) ≠ 0, the condition applies only to the energy group indicated by BLKGRP(N,1). Used only by two-dimensional diffusion subroutines (NBLACK is set to 0 in RCDEP)
BMN	R*8	(NGKMX,NGPMX, KMAX-1)	SYNGEN(PUTPNT) SYNGEN(WIPOUT)	M-COFGEN	B _{gk} for all groups g and all required synthesis regions k
BNDC JBNDK	R*4 I*4	(1,NBCDEF)	BNDC(PUTPNT)	S-STORBC	For each boundary condition NBC(NBC=1,NBCDEF), 11 terms, defined as follows JBNDK(1,NBC)-alphanu- meric name indicating whether this boundary con- dition applies to a vertical (VER) or horizontal (HOR) line. JBNDK(2,NBC)-vertical or horizontal mesh-line num- ber, positive if the condition applies on the top or the right side of the line, nega- tive if it applies on the left or bottom

Name	Type	Dimension	Subroutines Issuing Significant POINTER Calls	Subroutines Where Values Are Set or Modified	Definition
BNDC (1000)					upper and lower mesh-line numbers defining the interval over which this boundary condition applies. JBNDC(3,NBC) - number of initial (higher) energy group to which condition applies. JBNDC(4,NBC) - number of final (lower) energy group to which condition applies. JBNDC(7,NBC) - boundary condition type number. 1--C ₁ 0, C ₁ 0--C ₁ 2--C ₁ D0 + C ₁ 0 = C ₁ D ₁ where D is the diffusion coefficient BNDC(8,NBC) = C ₁ BNDC(9,NBC) = C ₂ BNDC(10,NBC) = C ₃ BNDC(11,NBC) = C ₄ (not currently used).
BSQ	R*8	(RMAX)	RGEOM(PUTPNT)	S-RMESH	Buckling values from data set GEOM when applicable. If B ² is not defined for a given region, BSQ(R) = 0.
CHI	R*8	(CHDIM,GMAX)	RCOMP(PUTPNT)	S-RGROUP	Fission-spectrum fractions stored as vectors (χ_g) or matrices ($\chi_g^{(k)}$) for each fissionable composition. [Note: that the synthesis module cannot handle matrices.]
CMN	R*8	(NGKMX,NGKMX,KMAX-1)	SYNGEN(PUTPNT) SYNGEN(WIPOUT)	M-COGEN	$\chi_g(k+1)$ for all groups g' and all required synthesis regions k.
CMPMSH	I*2	(JMAX,IMAX)	RGEOM(PUTPNT)	S-MESH	Mesh-to-composition correspondence, defined in data set GEOM. For any mesh interval (i,j), CMPMSH(i,j) is the number of the composition defined in interval (i,j).
CMPNAM	R*8	(CMAX)	COMP(PUTPNT)	S-RXSCO	Composition names, defined in data set XS C MIN. CMPNAM(C) is the name of the composition whose number is C.
CMPREG	I*2	(RMAX)	GEOM(PUTPNT)	S-MESH	Region-to-composition correspondence.
CNUM	R*8	(IMAX)	2DOUT(PUTPNT)	S-FLUXPR	X-direction mesh interval centers for output prints.
CRDUM	I*4	(RMAX)	GEOM(PUTPNT)	S-MESH	Temporary storage for region-to-composition correspondence array as read from data set GEOM (stored in I*2 array CMPREG).

Name	Type	Dimension	Subroutines Issuing Significant POINTN Calls	Subroutines Where Values Are Set or Modified	Definition
DC	R*8	(CMAX,GMAX)	RCOMP(PUTPNT)	S-RGROUP	Diffusion coefficients by composition and group. Diffusion coefficients are formed from the transport coefficients which are read into this array from data set XS-C MIN [DC = 1/(3*TR)]
DCCH	R*8	(NFAM,GMAX) for kinetics option 1 or 2 (0) for kinetics option 0	RCOMP(PUTPNT) RCOMP(WIPOUT)	S-RGROUP	Delayed neutron-emitter-yield spectrum λ^g by family and group, from data set XS DELAY (Kinetics option is set to 0 in RCDEP)
DECCDN	R*8	(NFAM) for kinetics option 1 or 2 (0) for kinetics option 0	RCOMP(PUTPNT) RCOMP(WIPOUT)	S-RDELAY	Decay constants by family for delayed neutrons from data set XS DELAY (Kinetics option is set to 0 in RCDEP)
DICH	R*8	(NFAM,GMAX) for kinetics option 2 (0) for kinetics option 0 or 1	RCOMP(PUTPNT) RCOMP(WIPOUT)	S-RDELAY	Delayed-neutron spectrum λ^g by family and group, from data set XS DELAY (Kinetics option is set to 0 in RCDEP)
DMN	R*8	(NGKMX,NGKMX,KMAX,j)	SYNGEN(PUTPNT) SYNGEN(WIPOUT)	M-COGEN	$B_g(k,i)$ for all groups g and all requested synthesis regions k
DNSCT	I*4	(GMAX)	RCOMP(PUTPNT)	S-RGROUP	Number of groups of down-scattering given for each group in a given composition block in data set XS C MIN
DRRMN	R*8	(NGKMX,NGKMX,RRMAX)	SYNGEN(PUTPNT) SYNGEN(WIPOUT)	M-COGEN	$D_{gk}(r)$ for all groups g and all refined regions r
DX	R*8	(IMAX)	RGEOM(PUTPNT)	S-RMESH	Lengths of X-direction mesh intervals
EXTHHT	R*8	(RMAX)	RGEOM(PUTPNT)	S-RMESH	Extrapolated region half-height read from data set GEOM. If BSQ(R) = 0.0 EXTHHT(R) = 0.0
F	R*8	(RMAX,GMAX)	B2DOUT(PUTPNT)	S-RCBAL	Fission-source integral F(R,G) by region and group for output edit
FG	R*8	(GMAX)	B2DOUT(PUTPNT)	S-FCOAL	Fission-source integral by groups $FG(G) = \sum_{R=1}^{RMAX} F(R,G)$
FIXXS	R*8	(RSCMAX,GMAX)	RCOMP(PUTPNT)	S-RGROUP	Fission cross section by composition and group, from data set XS-C MIN. Data are stored only for fissionable compositions
FIXXSC	R*8	(IMAX,JMAX) for source calculation (0) for k-effective calculation	B2DOUT(PUTPNT)	S-IFXVOL	External fixed source by interval and group 1) From data set ES.D2Q, weighted using fission-spectrum weighting over groups, if desired, and/or 2) From external delayed-neutron source, used when KNOPT = 1 (Module SYN2D cannot handle an external source)

Name	Type	Dimension	Subroutines Issuing Significant POINTER Calls	Subroutines Where Values Are Set or Modified	Definition
FLUX	R*8	(IMAX,JMAX)	D2DOUT(PUTPNT)	M-IFXVOL M-IGPCAL	Temporary storage for two-dimensional fluxes for energy group G
FLEX	R*8	(NGKMX,IMAX)	SYNGAL(PUTPNT) SYNGAL(WIPOUT)	M-SINCAL	Temporary storage for the mixing function iterates for the Gth group. It is compared with Φ_G for convergence and then stored in Φ_G
FR	R*8	(IMAX,JMAX) (RMAX)	SYNOUT(PUTPNT) SYNOUT(WIPOUT) D2DOUT(PUTPNT)	M-SINOUT S-ITOBAL	The reconstructed flux, which is calculated in SINOUT Fission source integral by regions
FSCMP	I*2	(CMAX)	RCOMP(PUTPNT)	S-GROUP	Indices corresponding to fissionable compositions. For any composition C, if FSCMP(C) = 0, C is not a fissionable composition, if FSCMP(C) is some nonzero integer, it is the position of that composition in arrays dimensioned with FSCMAX
FV	R*8	(RMAX,GMAX)	D2DOUT(PUTPNT)	S-IFXVOL M-IFXNRM	Regional flux integrals by group for output edit, normalized for k-effective calculations, not normalized for source calculations
GINT	R*8	(NGKMX,NGKMX, IMAX-1)	SYNGEN(PUTPNT) SYNGEN(WIPOUT)	S-CALC2 M-MTGEN2	Temporary storage for the matrices G_i , $i = 1, 2, \dots, IMAX - 1$ for a given energy group. These matrices are generated in CALC2. Later, in MTGEN2, we store $U_i^{-1}G_i$ for $i = 1, 2, \dots, IMAX - 1$ in GINT
G&PT	R*8	(GMAX)	D2DOUT(PUTPNT)		Not used
HADJG	R*8	(JMAX,NGKMX,2) (NGKMX,2)	RSDEF(REDEF) SDEF(REDEF) YNGEN(WIPOUT)	M-PROCS M-BCONDS	Temporary storage for two sets of adjoint trial functions which correspond to the real trial functions held by array HG Temporary storage for the calculated values on the reactor top and bottom of the adjoint trial functions. These values correspond to the real trial-function values held by array HG and are used in calculating the boundary matrices
HADJR	R*8	(JMAX,NGKMX,2)	SDEF(REDEF)	M-PROCESS	Temporary storage for two sets of adjoint trial function derivatives for the synthesis regions and energy groups, corresponding to the adjoint trial functions held by array HADJG

Name	Type	Dimension	Subroutines Issuing Significant POINTR Calls	Subroutines Where Values Are Set or Modified	Definition
HADJP (Contd)		(NGKMX,2)	RSDEF(REDEF) SYNGEN(WIPOUT)	M-BCONDS	Temporary storage for the derivatives of the adjoint trial functions calculated for the reactor top and bottom. These derivatives correspond to the function values held by array HADJG and are used in calculating the boundary matrices.
HG	R*8	(JMAX,NGKMX, GMAX*(KMAX+1)) or (JMAX,NGKMX, MAX(GMAX,KMAX))	RSDEF(PTCPNT)	M-LIB	Temporary storage used in generating the code-required library in subroutine LIB. The dimensions of the array depend upon whether the trial functions can be held in core for the library creation (first dimension) or not.
	R*8	(JMAX,NGKMX,2)	RSDEF(REDEF)	M-PROCES	Temporary storage for two sets of real trial functions for various synthesis regions and energy groups when calculating the partial integrals in subroutine process. Refer to PROCES for more details.
	R*8	(NGKMX,2)	RSDEF(REDEF)	M-BCONDS	Temporary storage for the calculated values on the reactor top and bottom of each real trial function for a particular synthesis region and energy group. These numbers are used in calculating the boundary matrices.
	R*8	(JMAX,NGKMX)	SYNOUT(PTCPNT) SYNOUT(WIPOUT)	M-SYNOUT	Temporary storage for the real trial functions when reconstituting the two-dimensional flux.
HINT	R*8	(NGKMX,NGKMX, IMAX-1)	SYNGEN(PTCPNT) SYNCAL(WIPOUT)	M-CALC2 M-SINCAL	Contains $H_{i+1, 1} - 1, 2$. $IMAX - 1$ for all energy groups G . H_{i+1} is stored in HINT(1,1,1). H_{i+1} is calculated in CALC2 and later written out in subroutine MTGEN2. The matrices H_{i+1} and G_i are later stored here in subroutine SINCAL.
HP	R*8	(JMAX,NGKMX,2)	RSDEF(REDEF)	M-PROCES	Temporary storage for two sets of real trial-function derivatives for the synthesis regions and energy groups corresponding to the function presently held in array HG. These derivatives are used in calculating the partial integrals computed in PROCES.
		(NGKMX,2)	RSDEF(REDEF) SYNGEN(WIPOUT)	M-BCONDS	Temporary storage for the derivatives of the real trial functions calculated for the reactor top and bottom. These derivatives correspond to the function values held by array HG and are used in calculating the boundary matrices.

Name	Type	Dimension	Subroutines Issuing Significant POINTR Calls	Subroutines Where Values Are Set or Modified	Definition
IDSNO	I*2	(MAX(GMAX,4))	RSDEF(PUTPNT) RSDEF(WIPOUT)	S-LIB	GMAX scratch data-set reference numbers, if the trial functions cannot be core-contained when generating the code-used trial function library. These reference numbers refer to scratch data sets, which will be used to generate the library data sets.
IFLAGS	I*4	(IMAX)	SYNGEN(PUTPNT) SYNGEN(WIPOUT)	S-CHECK	Synthesis-region indicator. IFLAGS(1) = 0 implies that the right endpoint of interval J, i.e., X(1+1), is not a synthesis boundary, while IFLAGS(1) = 1 implies that it is.
IPNT	I*2	(GMAX)	RSDEF(PUTPNT) RSDEF(WIPOUT)	M-LIB	Required if the trial functions are not core-held during the library generation. In this case, GMAX scratch data sets are used, one for each group. The number IPNT(G) indexes the arrays LWHRNO and LWHRSR. These arrays locate all the required trial functions for energy group G, which have been stored on the data set whose reference number is IDSNO(G).
JUNK	R*8	(NGKMX,NGKMX)	SYNGEN(PUTPNT)	M-MTGEN M-CALC1	Temporary storage for $D_g(r)$, where r is first l and then RMAX, that is, the diffusion matrix for the first and last refined region.
L	R*8	(RMAX,GMAX)	D2DOUT(PUTPNT)	S-IRGBAL	Leakage by region and group for output edits.
LI	I*4	(NGKMX)	SYNGEN(PUTPNT) SYNGEN(WIPOUT)	M-MINV	Temporary storage.
LG	R*8	(GMAX)	DOUT(PUTPNT)	S-ITOBAL	Leakage by groups. $LG(G) = \sum_{R=1}^{RMAX} L(R,G)$
LIBFLX	I*2	(GMAX,KMAX,MAXNUM)	REF(PUTPNT) REF(WIPOUT)	S-SYNDEF	LIBFLX(G,K,N) tells which function on the input trial function libraries is the Nth trial function for the Kth synthesis region and the Gth energy group.
LWHRNO	I*2	(GMAX,KMAX*NGKMX)	REF(PUTPNT)	S-LIB	Used when the trial functions required to generate the trial-function libraries cannot be core-contained. Each scratch data set (data-set reference number IDSNO(G)) contains all the trial functions for group G. The number N = LWHRNO(G,1) indicates which trial function is contained in the 1th record. Refer to LWHRSR.

Name	Type	Dimension	Subroutines Issuing Significant POINTER Calls	Subroutines Where Values Are Set or Modified	Definition
LWHRSR	1*2	(GMAX,KMAX*NGKMX)	RSDEF(PUTPNT) RSDEF(WIPOUT)	S-LIB	Refer to I WHRNO the number K = LWHRSR(G,I) indicates which synthesis region the trial function in the Ith record belongs in. Hence the arrays LWHRNO and LWHRSR indicate for each scratch data set, the energy group, synthesis re- gion and function number of every function stored on that scratch data set.
M1	1*4	(NGKMX)	SYNGEN(PUTPNT) SYNGEN(WIPOUT)	M-MINV	Temporary storage
MSHCMP	1*4	(IMAX,JMAX)	RGEOM(PUTPNT) RGEOM(WIPOUT)	S-RMESH	Temporary storage for mesh-to-composition corre- spondence as read from data set GEOM (stored in 1*2 array CMPMSH).
MSHREG	1*4	(IMAX,JMAX)	RGEOM(PUTPNT) RGEOM(WIPOUT)	S-RMESH	Temporary storage for mesh-to-region correspond- ence as read from data set GEOM (stored in 1*2 array REGMSH).
NBP	1*4	(GMAX,KMAX)	RSDEF(REDEF) SYNCAL(REDEF) SYNOUT(WIPOUT)	M-PROCES M-DSRNCK M-SYNCAL	Used to check the data sets after a restart for consis- tency with the current problem.
NUMRRJ	1*4	(GMAX*KMAX)	SYNGEN(PUTPNT) SYNGEN(WIPOUT)	S-COGEN	The array NUMRRJ from the old data set LIB PAB. This array is compared with the current NUMRRJ array.
NN	1*2	(GMAX,KMAX)	RSDEF(PUTPNT) SYNOUT(WIPOUT)	S-SYNDEF	The number of trial functions in energy group G, synthesis region K.
NNP	1*2	(0)	PSDEF(PUTPNT) SYNOUT(WIPOUT)		A dummy array allocated im- mediately before array NN. Hence both arrays are equivalenced and any refer- ence to NNP(G,K) actually obtains NN(G,K). This array is a remnant from an earlier version of the code.
NTRIAL	1*2	(GMAX*KMAX*MAXNUM (NTRL))	RSDEF(PUTPNT) RSDEF(REDEF) SYNGEN(WIPOUT)	S-SYNDEF	Refer to array NZERO. The numbers stored in NTRIAL should be only 0 or 1, indi- cating that the functions do or do not satisfy the imposed boundary condition $\psi = 0$. The size of NTRIAL is rede- fined after returning from SYNDEF. The number NTRL is the actual storage required.
NUFIS	R*8	(FSCMAX,GMAX)	RCOMP(PUTPNT)	S-RGROUP	W of cross section by compo- sition and group, where ν is the number of neutrons re- leased per fission for that group, from data set XS C.MIN.

Name	Type	Dimension	Subroutines Issuing Significant POINTN Calls	Subroutines Where Values Are Set or Modified	Description
NUMRJI	1*2	(KMAX)	RSDEF(REDEF) SYNGEN(WIPOUT)	S-PRCALC	The number of 1/2 correction refined intervals for synthesis region.
NUSIGF	R*8	(NGKMX,NGKMX,GMAX, MANY)	RSDEF(R1DEF) SYNGAL(REDEF) SYNGAL(WIPOUT)	M-COFCEN M-SINGAL	Temporary storage for the fission matrices, which are calculated as synthesis region at a time for all groups in COFCEN and then read in for one refined region and group at a time in SINGAL.
NZERO	1*2	(GMAX,KMAX)	RSDEF(PUTPNT) SYNGEN(WIPOUT)	S-SYNDEF	Used to index the array NTRIAL. Normally, NZERO(G,K) is set to zero and NTRIAL is not referenced. If however, the user specifies that for a given group G and synthesis region K the axial functions may or may not satisfy the imposed boundary condition, $\neq 0$, this information is then stored in array NTRIAL and starts at NTRIAL(NZERO(G,K)).
PHI	R*8	(NGKMX,IMAX,GMAX)	SYNGAL(PUTPNT) SYNGEN(WIPOUT)	M-SINGAL	The calculated mixing functions.
PHI2	R*8	(NGKMX,IMAX,GMAX)	SYNGAL(PUTPNT) SYNGEN(WIPOUT)	M-SINGAL	The calculated mixing functions for each group, collected until the iteration has been completed. The mixing functions are then passed to array PHI.
PHYREG	1*2	(IMAX)	RSDEF(PUTPNT) RSDEF(WIPOUT)	S-PRCALC	PHYREG(I) tells in which physical region the Ith interval lies.
POWERFI	R*8	(JMAX,IMAX)	D2DOUT(PUTPNT)	S-FLUXPR	Total power density by mesh interval.
PR	R*8	(RMAX)	D2DOUT(PUTPNT)	S-IPXNRM	Power by region.
RAF	R*8	(RMAX,GMAX)	D2DOUT(PUTPNT)	S-IPXNRM	Region-averaged flux integrals by group, for output edit and for data set ER.PN.
RAFS	R*8	(RMAX,GMAX)	D2DOUT(PUTPNT)	S-ITOBAL	Region-averaged fission-source integral by group, for output edit.
REGHHT	R*8	(RMAX)	RGEOM(PUTPNT)	S-RMESH	Actual region half-height read from data set GEOM. If $BSQ(R) = 0.0$, $REGHHT(R) = 0.5$.
REGMSH	1*2	(IMAX,IMAX)	RGEOM(PUTPNT)	S-RMESH	Mesh-to-region correspondence defined in data set GEOM. For any mesh interval (I,J), REGMSH(I,J) is the number of the reactor region to which (I,J) belongs.
REGNAM	R*8	(RMAX)	RGEOM(PUTPNT)	S-RMESH	Region names defined in data set GEOM. REGNAM(R) is the name of the region whose number is R.

Name	Type	Dimension	Subroutines Issuing Significant POINIR Calls	Subroutines Where Values Are Set or Modified	Definition
REM	R*8	(C MAX G MAX)	RCOMP/PUTPNT	S-RGROUP	Removal cross section σ_R by composition and group from data set N C MIN.
RESULT	R*8	MAX[(NGKMX NGKMX, NUMMAX),(NGKMX,4)]	RSDEF(REDEF) SYNGEN(WIPOUT)	M-PROCES M-VALUES	Temporary storage for the partial integrals computed in PROCES RESULT is also used to temporarily hold the extrapolated values of the trial functions computed in VALUES at the reactor top and bottom NUMMAX is the maximum number of Y-direction refined intervals per synthesis region
RG	R*8	(G MAX)	DZDOUT(PUTPNT)	S-ITOBAL	Removal by groups $RG(G) = \sum_{R=1}^{RMAX} RMVL(R,G)$
RMVL	R*8	(R MAX G MAX)	DZDOUT(PUTPNT)	S-IRGBAL	Removal contribution to balance by region and group for output edit, including α/v and DB^2 terms
RNUM	R*8	(J MAX)	DZDOUT(PUTPNT)	S-FLUXPR	Y-direction mesh interval center for output prints
ROOM	R*8	(NGKMX NGKMX)	SYNGEN(PUTPNT) SYNGEN(WIPOUT)	M-MTGEN1 M-CALG1 M-CALC2	Temporary matrix storage
RR	I*2	(I MAX)	RSDEF(PUTPNT) SYNGEN(WIPOUT)	S-RRCALC	RR(I) tells in which refined region the Ith interval lies (Used in subroutines as array REFREG)
		(R MAX)	DZDOUT(PUTPNT)	S-ITOBAL	Removal contribution to balance by region for output edit, including α/v and DB^2 terms
RRFJ	I*2	(R MAX J MAX)	RSDEF(PUTPNT)	S-RRCALC	The set of first intervals of each Y-direction refined interval for all synthesis regions
		(L LEN)	RSDEF(REDEF) SYNGEN(WIPOUT)		The size of RRFJ is redefined after returning from RRCALC to use only the required storage (LLEN)
RRFRST	I*2	(I MAX)	RSDEF(PUTPNT)	S-RRCALC	RRFRST(R) is the first interval of refined region R
		(R R MAX)	RSDEF(REDEF) SYNGEN(WIPOUT)		The size of RRFRST is redefined after the call to RRCALC to use only the required storage (RRMAX)
RRJLOC	I*2	(K MAX J)	RSDEF(REDEF) SYNGEN(WIPOUT)	S-RRCALC	Index for the array RRFJ. RRJLOC(K) indicates where the first interval of the first Y-direction refined interval of synthesis region K is stored.
RV	R*8	(R MAX)	DZDOUT(PUTPNT)	S-IFXYOC M-IFXYOC	Physical region volume. When the third dimension is infinite, RV is the region volume per unit height.

Name	Type	Dimension	Subroutines Issuing Significant POINTS, all	Subroutines Where Values Are Set or Modified	Definition
S	R*8	(RMAX,GMAX)	D2DOUT(PUTPNT)	S-IRGHAL	Scattering contribution to balance by region and group for output edit.
SCTCOF	R*8	(NGKMX,NGKMX, GMAX-1,MANY)	RSDEF(REDEF) SYNGEN(WIPOUT)	M-COFGEN	Temporary storage for the scattering matrices, which are calculated a synthesis region at a time for all groups in COFGEN and then written out.
SCTDUM	R*8	(SCTDIM,GMAX)	RCOMP(PUTPNT) RCOMP(WIPOUT)	S-RGROUP	Array used to read in full scattering cross sections before packing into SCTXS.
SCTLIM	I*2	(2,CMAX)	RCOMP(PUTPNT)	S-RGROUP	Scattering-array bandwidths for each composition C. SCTLIM(1,C) is the maximum width of the upscattering band for composition C, and SCTLIM(2,C) is the maximum width of the downscattering band. SCTLIM(1,C) + SCTLIM(2,C) + 1 is the maximum bandwidth.
SCTLOC	I*2	(CMAX,GMAX)	RCOMP(PUTPNT)	S-DIMSCT M-REKSCCT	Location of specified scattering band in SCTXS. For a given composition C and group G, SCTLOC(C,G) gives the location of the band of elements of SCTXS.
SCTXS	R*8	(SCTDIM,GMAX)	RCOMP(PUTPNT)	S-RGROUP	Scattering cross section of σ_g by composition, bandwidth, and group, packed from SCTDUM.
SETCHI	R*8	(ISCHI,GMAX)	RCOMP(PUTPNT) RCOMP(WIPOUT)	S-GETCHI	Set-wide fission spectrum χ_g^S , if one is defined in data set XS C MIN. Values are transferred into the CHI array for compositions using the set-wide χ_g^S .
SG	R*8	(GMAX)	D2DOUT(PUTPNT)	S-ITOBAL	Scattering by groups. $SG(G) = \sum_{R=1}^{RMAX} S(R,G)$
SIGMA	R*8	(NGKMX,NGKMX, RMAX)	YNGEN(PUTPNT) YNGEN(WIPOUT)	M-COFGEN M-BCONDS	The sum of the two matrices $(\Sigma_p)_{gh}(r)$ and $(\Sigma_{ph})_{gh}(r)$ for energy group G and all refined regions, calculated and stored in COFGEN. $C_{gh}(r)$ is added in subroutine BCONDS.
SRC	R*8	(RMAX)	DOUT(PUTPNT)	S-ITOBAL	External source by groups output edit. $(G) = \sum_{R=1}^{RMAX} SV(R,G)$
SRC	R*8	(RMAX)	T(PUTPNT)	S-ITOBAL	Source by regions output edit. $(R) = \sum_{G=1}^{GMAX} SV(R,G)$

Name	Type	Dimension	Subroutines Issuing Significant POINTR Calls	Subroutines Where Values Are Set or Modified	Definition
SPACE	R*8	(NGKMX,NGKMX)	SYNGFN(PUTPNT) SYNGEN(WIPOUT)	M-MTGEN1 M-CALC1 M-CALC2	Temporary matrix storage
SR	R*8	(RMAX)	D2DOUT(PUTPNT)	S-ITOBAL	Scattering contribution balance by region and group for output edit
SV	R*8	(RMAX,GMAX)	D2DOUT(PUTPNT)	S-IFXVOL	External source by region and group for output edit, in- cluding external source due to inhomogeneous interface conditions and to delayed data, if present.
SYNMSH	I*2	(IMAX)	RSDEF(PUTPNT) SYNOUT(WIPOUT)	S-SYNDEF	SYNMSH(I) tells in which synthesis region the Ith in- terval lies.
T	R*8	(RMAX,GMAX)	D2DOUT(PUTPNT)	S-IRGBAL	Output balance by regions and groups, $T(R,G) =$ $-L(R,G) - RMVL(R,G) +$ $S(R,G) + F(R,G)/KEFF$ for a k-effective calculation
TG	R*8	(GMAX)	D2DOUT(PUTPNT)	S-ITOBAL	Output balance by groups, $TG(G) = \sum_{R=1}^{RMAX} T(R,G)$
TR	R*8	(RMAX)	D2DOUT(PUTPNT)	S-ITOBAL	Output balance by regions, $TR(R) = \sum_{G=1}^{GMAX} T(R,G)$
UINT	R*8	(NGKMX,NGKMX,IMAX)	SYNGEN(PUTPNT) SYNCAL(WIPOUT)	M-CALC2 M-MTGEN2 M-SINCAL	E_i for $i = 1, 2, \dots, IMAX$, generated in CALC2, U_i^j , $i = 1, 2, \dots, IMAX$, calcu- lated in MTGEN2 and then written out, U_i^j , $i = 1, 2,$ $IMAX$ for group G during iterations, calculated in SINCAL
UPSCAT	I*4	(GMAX)	RC MP(PUTPNT) RC MP(WIPOUT)	S-RGROUP	Number of groups of up- scattering given for each group in a given composition block in XS C MIN
VEL	R*8	(GMAX)	RC MP(PUTPNT)	RVEL	Neutron speeds, set to 1, for all groups.
WINT	R*8	(IMAX)	S AL(PUTPNT) AL(WIPOUT)	S-SINCAL	$WINT(i) = DX(i)$ in XY or ZR geometry, $WINT(i) =$ $DX(i) * [X(i) + DX(i)/2]$ in RZ geometry.
WMN	R*8	(NGKMX,NGKMX)	S GEN(PUTPNT) SY GEN(WIPOUT)	M-COFGEN	$W_{g,k}$ for energy group g and the last synthesis region k .
WORK	R*8	(NGKMX,NGKMX)	SY GEN(PUTPNT) S EN(WIPOUT)	M-MTGEN1 M-CALC1 M-CALC2	Temporary matrix storage
X	R*8	(IMAX+1)	R OM(PUTPNT)	S-RMESH	X-direction mesh-line locations
XYNDEF	R*8	(IMAX+1)	R EF(PUTPNT) EF(WIPOUT)	S-SYNDEF	Synthesis boundaries ex- cluding the origin. (Only the first IMAX words are used.)

Name	Type	Dimension	Subroutines Issuing Significant POINTR Calls	Subroutines Where Values Are Set or Modified	Definition
Y	R*8	(JMAX+1)	RCFORM PLTPNT	Y-RMESH	Y-direction mesh-line locations
AMN	R*8	(NGKMX,NGKMY)	SYNGEN PUTPNT SYNGEN WIPQUT	M-COFGIN	Wgt. for energy group g and the first synthesis region

D Subroutine Descriptions

This section describes all subroutines that are part of the SYN2D module. The descriptions appear in alphabetical order by subroutine name.

Each subroutine description begins with a listing of the calling sequence of the routine and of its entry points, if any. Subsection a is a list of the arguments to the subroutine and its entry points. For arguments defined in any common block, the name of the common block is noted. Other arguments are listed in their order of appearance, with the type of each argument, its dimension in the subroutine if it is an array, and its definition or use. The four types of variables used are I*2, denoting an integer half-word (16 bits), I*4, denoting an integer fullword (32 bits), R*4, denoting a floating-point fullword (32 bits), and R*8, denoting a floating-point double-word (64 bits).

Arrays or variables from a common block which are used in a subroutine are defined in the documentation for their respective common blocks.

Subsection b contains a listing of important variables which are local to the subroutine, in a format like that of Subsection a.

Subsection c describes the functions performed by the subroutine in terms of the overall purpose of the module, where applicable. Refer to Section II.B. when a more detailed description or explanation is required.

Subsection d lists all subroutines called by this subroutine. Subroutine entry points called by this subroutine are not listed if the main subroutine entry is also called. Thus, if this subroutine invokes subroutine A and also entry point AA of subroutine A, only A will appear in the list of Subsection d. If, however, this subroutine invokes only entry point AA, then AA will appear in the list. POINTR, BULK, and FREE are the only entry points of the dynamic storage subroutines listed. POINTR entry points PUTPNT, BETPNT, IGET, WIPQUT, etc. are not listed in Subsection d.

Subsection e lists all subroutines that call this subroutine.

1 Subroutine BCONDYHC HP HADIG, HADIP RRFRST, SIGMAR,
CMPMSH DC NZERO NN NIBIAL, CMAX JMAX GMAX IMAX,
RRMAX NGKMX LPART, *

Entry point.

Entry BNDCONDIG, RI, LASTRI, K, *

a Arguments: The first 11 arguments of the main calling sequence appear in the common block BLKSLK. The remaining seven arguments of the main calling sequence are members of the common block SINGLE. The optional return and the entry point arguments are defined below.

<u>Name</u>	<u>Type</u>	<u>Definition</u>
*	-	Error return to calling subroutine
G	I*4	Present energy group
RI	I*4	First refined region of synthesis region K
LASTRI	I*4	Last refined region of synthesis region K
K	I*4	Present synthesis region

b Important Local Variables

<u>Name</u>	<u>Type</u>	<u>Definition</u>
MPLACE	I*4	Has significance only if the boundary condition is $\phi \neq 0$, when it represents m in Subsection c(3) below
NPLACE	I*4	Has significance only if the boundary condition is $\phi \neq 0$ when it represents n in Subsection c(3) below
NUMBER	I*4	Location in the array NTRIAL where the boundary condition information on the trial functions is stored

c Functions and Tasks Performed by This Subroutine. This subroutine calculates the boundary-condition matrices for the top and bottom of the reactor in synthesis region K and energy group G for each refined region. Each boundary matrix, after it is computed, is added to the contents of the array SIGMAR, which already contains the sum of the matrices L and L_r for that refined region. The boundary condition applied at the reactor top (or bottom) must be invariant in each refined region for group G, but may be group-dependent. The changing of the boundary condition at the top face is completely independent of the boundary-condition changes at the bottom face.

The three boundary conditions allowed at each face for each refined region and the matrices generated in each case are as follows

(1) If $\varphi = 0$ no matrix is generated

(2) If $\varphi = \frac{\beta}{D} \varphi =$ no matrix C is generated where

$C^{mn}(a) = \beta H_g^{*m}(a) H_g^n(a)$ and a can be 0 or h for the reactor bottom or top respectively β is the user-supplied constant and D is the diffusion coefficient at that particular face

(3) If $\varphi \neq 0$ the matrix C is generated, where

$$C^{mn}(a) = \omega D \left[H_g^{*m}(a) \frac{dH_g^n}{dy} \Big|_{y=a} + H_g^n(a) \frac{dH_g^{*m}}{dy} \Big|_{y=a} \right]$$

$\omega = 1$ or -1 depending upon if $a = 0$ or h , respectively D and a are defined as above

If the user has indicated that certain of the trial functions in a particular synthesis region satisfy the boundary condition $\varphi = 0$, then the entire matrix as defined above need not be calculated. Now, if a trial function $\bar{m}$ is zero at the boundary, its adjoint is also zero. The elements C^{mn} for m and $n \neq \bar{m}$ are calculated as defined above. However if $m = \bar{m}$ only the second part of the computation need be performed. Conversely, if $n = \bar{m}$, only the first half of the computation is performed. Finally, if $\varphi = 0$ at both the reactor top and bottom it is assumed that if a trial function satisfies the top condition is also satisfies the bottom condition. This is the only case in which this assumption is made. Note that the values stored in HG, HADJG, HP and HADJP are the actual computed function values and derivatives at the reactor faces

d Subroutines Call d by This Subroutine HORBND (entry in GETBND) ERRMSG

e. Subroutine Call: This Subroutine COFGEN.

2 Subroutine CALCI(N KMX,NGKPMX,SYNMSH,REFREG NN, NNP,DRRMN,AMN,B N,CMN,DMN,IFLAGS,AREA,ROOM SPACE,WORK,DX,LI 1,IM1,KBAR,GMAX,RRMAX,KMAX,IMAX,JUNK)

Entry points

Entry. CLCI(*,G,I,Z ORM)

a Arguments The constants NGKMX NGKPMX GMAX RRMAX KMAX and IMAX appear in common block SINGLE. The constants IM1 and KBAR are IMAX - 1 and KMAX - 1 respectively. The remaining arguments in the calling sequence are located in common block BLKSTR with REFREG listed as RR. The entry-point arguments are listed below.

<u>Name</u>	<u>Type</u>	<u>Definition</u>
G	I*4	Present energy group
I	I*4	Present interval for which we want Ω_I .
ZNORM	R*8	Condition number of $D_{gk}(r)$

b Important Local Variables

<u>Name</u>	<u>Type</u>	<u>Definition</u>
K	I*4	Used in dimensioning matrices
IRR	I*4	Refined region in which interval I lies.
NNN	I*4	Rank of Ω^{-1}
DET	R*8	Determinant of $D_{gk}(r)$
XNORM	R*8	Column norm of $D_{gk}(r)$
YNORM	R*8	Column norm of $[D_{gk}(r)]^{-1}$
NGKP	I*4	One dimension of some of the coefficient matrices used

c Functions and Tasks Performed by This Subroutine. This routine calculates the condition number ZNORM of $D_{gk}(r)$, the diffusion matrix, and Ω_I^{-1} which is stored in array AREA. The number ZNORM is calculated as XNORM*YNORM and is just a crude attempt to calculate a norm for the matrix $D_{gk}(r)$. The larger this norm the less linearly independent are the associated trial functions. The matrix Ω_I is defined by

$$\Omega_I = \frac{1}{2} [\delta_1 A D_{gk}^{-1}(r_1) B + \delta_{1+} C D_{gk}^{-1}(r_{1+1}) D],$$

where δ_1 is the length of mesh interval 1 and r_1 is the refined region in which the 1th interval lies.

The matrices A, B, C, and D will be the identity matrix if intervals 1 and 1 + 1 lie in the same synthesis region; otherwise $A = A_k$, $B = B_k$, $C = \bar{A}_k$, and $D = \bar{B}_k$. These matrices are stored in arrays AMN, BMN, CMN, and DMN, respectively. Refer to Section II.B. for more information on how Ω_I is calculated. Notice that if the intervals lie in different synthesis regions $D_{gk}^{-1}(r_{1+})$ is calculated and stored in the same array space as $D_{gk}(r_{1+1})$ was originally stored.

d. Subroutines Called by This Subroutine. NORM, MINV, NUMMLT, MADD, GMPRD, ERRMSG.

e. Subroutine Calling This Subroutine. MTGEN1.

3. Subroutine CALC2(NGKMX, NGKPMX, SYNMSH, REFREG, NN, NNP, AMN, BMN, CMN, DMN, IFLAGS, DX, LI, MI, JMI, KBAR, GMAX, GINT, HINT, UINT, RRMAX, KMAX, IPOINT, JPOINT, KPOINT, LPOINT, X, IMAX, SIGMAR, NALPHA)

Entry points

Entry. CALC2(*, G, I, WINT)

a. Arguments. Arguments 3-14, 18-20, 27, and 29 of the calling sequence are listed in the common block BLKSTR with array REFREG listed as RR. Arguments 1, 2, 17, 21, 22, 28, and 30 are listed in common block SINGLE. The remaining calling sequence arguments and entry point arguments are listed below.

<u>Name</u>	<u>Type</u>	<u>Definition</u>
IMI	I*4	IMAX-1.
KBAR	I*4	KMAX-1.
IPOINT	I*4	Pointer for the array AREA in the common block BLKSTR.
JPOINT	I*4	Pointer for the array ROOM in the common block BLKSTR.
KPOINT	I*4	Pointer for the array SPACE in the common block BLKSTR.
LPOINT	I*4	Pointer for the array WORK in the common block BLKSTR.
*		Error return to calling subroutine.
G	I*4	Present energy group number.
I	I*4	Present x-direction interval number.
WINT	R*8	If NALPHA = 0, DX(I), i.e., δ_i . If NALPHA = 1, DX(I)*(X(I) + 0.5DX(I)), i.e., $\delta_i r_i$.

b. Important Local Variables

<u>Name</u>	<u>Type</u>	<u>Definition</u>
K	I*4	Synthesis region in which interval I lies.
NNN	I*4	Dimension of Δ^{-1} from CALC1.
RDX	R*8	R_I^2 , i.e., $X(I,1)**NALPHA$.
KM1	I*4	Synthesis region in which interval (I-1) lies.
IRR	I*4	Refined region in which interval I lies.
KP1	I*4	Synthesis region in which interval (I+1) lies.

c. Functions and Tasks Performed by This Subroutine

This routine generates the matrices G_I , H_{I+1} , and E_I for a given I. These matrices are stored in the arrays GINT, HINT and UINT for later use. The formulas used for generating these three matrices for each I are

$$G_I = x_{I+1}^\alpha B \bar{\Delta}^{-1} C, \quad 1 \leq I < IMAX, \quad (82)$$

$$H_{I+1} = x_{I+1}^\alpha D \bar{\Delta}^{-1} A, \quad 1 \leq I < IMAX, \quad (83)$$

$$E_I = x_I^\alpha B \bar{\Delta}^{-1} A + x_{I-1}^\alpha \bar{D} \bar{\Delta}_{I-1}^{-1} \bar{C} + \omega [L(r_I) + E_R(r_I) + \bar{C}(r_I)], \quad (84)$$

$2 < I < IMAX$

$$E_I = x_I^\alpha B \bar{\Delta}^{-1} A + C_2(1-\alpha) D_{g1}(r_I) \left[C_1 D_{g1}(r_I) + C_2 W_{g1} \frac{\delta_I}{2} \right]^{-1} W_{g1} \\ + \omega [L(r_I) + E_R(r_I) + \bar{C}(r_I)], \quad (85)$$

$$E_q = x_q^\alpha C_2 D_{gk}(r_q) \left[C_1 D_{gk}(r_q) + C_2 W_{gk} \frac{\delta_q}{2} \right]^{-1} W_{gk} + x_{q-1}^\alpha \bar{D} \bar{\Delta}_{q-1}^{-1} \bar{C} \\ + \omega [L(r_q) + E_R(r_q) + \bar{C}(r_q)], \quad (86)$$

where $\alpha = NALPHA$, $\omega = WIN$, $\delta_i = DX(I)$, $q = IMAX$, and r_i is the refined region in which interval I lies. The numbers C_1 and C_2 arise from the boundary conditions that are applied (i.e., $C_1 \varphi + C_2 \varphi' = 0$) at the reactor ends. The matrices $\{D_{gk}\}$, $\{L\}$, $\{E_R\}$, and $\{\bar{C}\}$ are the diffusion matrices, the double gradient matrices, the removal matrices, and the boundary condition matrices from the nonsynthesis direction, respectively, while the matrices W_{gk} are the synthesis-direction boundary-condition matrices. The matrices A , B , C , D , $\bar{C}$, and $\bar{D}$ vary, depending upon where the synthesis boundaries lie. There are four cases to consider.

I. If both x_{I+1} and x_{I+2} are synthesis boundaries, then $A = A_k$, $B = B_k$, $C = \bar{A}_{k+1}$, $D = \bar{B}_{k+1}$, $\bar{C} = \bar{A}_k$, and $\bar{D} = \bar{B}_k$.

II. If only x_{I+1} is a synthesis boundary then $A = B = C = D = I$ the identity matrix, and $\bar{C}$ and $\bar{D}$ are given in Case I above.

III. If only x_{I+2} is a synthesis boundary, then $\bar{C} = \bar{D} = I$ and A , B , C , and D are given in Case I above.

IV. If neither x_{I+1} nor x_{I+2} is a synthesis boundary, then $A = B = C = D = \bar{C} = \bar{D} = I$, the identity matrix.

The actual calculation of the matrices is straightforward, however, the following points should be noted:

- (1) Array $BLK(IPOINT)$ contains Ω_I^{-1} until no longer needed.
- (2) The matrix $x_{I+1}^a D \Omega_I^{-1}$ is calculated for the matrix H_{I+1} and temporarily stored in array $BLK(LPOINT)$, however, before leaving the routine, it is stored in array $BLK(KPOINT)$ for calculating the matrix E_{I+1} on the next pass.
- (3) $x_{I+1}^a B \Omega_I^{-1}$ is calculated for G_I and stored in $BLK(IPOINT)$ since Ω_I^{-1} is no longer needed. Later this matrix is used in computing E_I .
- (4) The first term of Eq. 85 is calculated in subroutine $MTGEN1$ and added to E_I just before leaving the subroutine $MTGEN1$.
- (5) The matrix specified by Eq. 86 is calculated in subroutine $MTGEN1$ using 2 above.

For a more complete description of the generation of these matrices see Section II B.

d. Subroutines Called by This Subroutine NUMMLT, MOVE, MADD, GMPRD.

e. Subroutine Calling This Subroutine MTGEN1.

4. Subroutine CHECK(IMAX, IFLAGS, SYNMSH)

a. Arguments. The number IMAX is listed in common block SINGLE. The arrays IFLAGS and SYNMSH are defined in common block BLKSTR.

b. Important Local Variables None.

c. Functions and Tasks Performed by This Subroutine This subroutine compares the x-direction intervals 1 and 1 - 1 to see if both lie in the same synthesis region. If both intervals do not lie in the same synthesis region then $LAGS(1-1)$ is set to one, otherwise, it is set to zero.

d. Subroutines Called by This Subroutine None

e. Subroutine Calling This Subroutine SYNGEN.

5. Subroutine CLOSE

a. Arguments None

b. Important Local Variables

<u>Name</u>	<u>Type</u>	<u>Definition</u>
IDSN	I*4	Flag used by subroutines OPENDS and CLOSE.
IDSRN(10)	I*4	The data set reference numbers of all open data sets

c. Functions and Tasks Performed by This Subroutine The purpose of this subroutine is to close all data sets that are open when this subroutine is called and to list each data set that has been rewound. The subroutine OPENDS returns the number IDSN and a partially filled array IDSARN. The absolute value of IDSN is the number of data sets that are open. IDSN is set to 10 before calling OPENDS to give the length of the array IDSARN. The first IDSN numbers of array IDSARN contain the data-set reference numbers to be rewound. Finally, after these data sets are rewound, another call to OPENDS will be made if IDSN was returned as a negative number by OPENDS indicating that more than 10 data sets were open.

d. Subroutines Called by This Subroutine OPENDS (ARC System subroutine), SNIFF (ARC System subroutine).

e. Subroutines Calling This Subroutine SYN2D, RSDEF, SYNGEN.

6. Subroutine COFGEN(RESULT,HC*HP,HEADMG,HEADJ*NN,
SIGMAR,AMN,BMN,(CMN DMN DRRMN,RRFRS,NUSIGF,
SCTCOF,NBP,NDLMR) NUMRRJ CMPMSH RRFJ,SYNMSH
SCTXS REGMSH REM DC BSQ WMN,ZMNFSCMP,CHI,LL,
MM,SPACE,AREA SCFLOC SCILIM NUHS RRLLOC TIMEKY,
CMAX,JMAX,NGKMX,GMAX,KMAX,IOPT,RRMAX,FSCMAX,
CHIDIM,IMAX,NALPHA,NBETA,GMI,SCTDIM,MAXDN,MAXUP,
IFISS,ISCAT,LPART*)

Entry points

Entry: COEFF(G*)

a. Arguments. The first 38 arrays are listed in the common block BLKSTR. The arrays LL and MM are listed as L1 and M1 respectively. The remaining arguments except GMI are listed in common block SINGLE, with IFISS and ISCAT listed as IEIB and MLIB respectively. Other arguments are listed below

<u>Name</u>	<u>Type</u>	<u>Definition</u>
GMI	I*4	GMAX-1
*		Error return to calling subroutine
G	I*4	Present energy group.

b. Important Local Variables

<u>Name</u>	<u>Type</u>	<u>Definition</u>
R1	I*4	The first refined region in synthesis region K
LASTRI	I*4	The last refined region in synthesis region K
IPNT	I*4	Index used to store the fission and scattering matrices
IP	I*4	Index used to properly pack the scattering matrices
I	I*4	Either the first or last interval in a refined region used to isolate proper cross sections
J	I*4	First interval in each Y-direction refined interval.
ICMP	I*4	Composition number used for indexing fission-related cross-section arrays, which indicates if greater than zero, the fission cross-section and x (if it is zero, the composition is not fissionable.)
NFSCMP	I*4	

<u>Name</u>	<u>Type</u>	<u>Definition</u>
GPLB	I*4	The lowest group into which downscattering occurs
GPHH	I*4	The highest group into which upscattering occurs
NEXTI	I*4	First interval of next refined region
NEXTRI	I*4	First refined region of next synthesis region
NUMBER	I*4	The number of Y-direction refined intervals in each synthesis region
IPOINT	I*4	Points to the location (less one), in array RRFJ where the first Y-direction interval number of the first Y-direction refined interval for synthesis region K is stored. The number in location (IPOINT + 1) is always 1, and the numbers stored in successive locations following it contain the first Y-direction interval numbers for the successive refined intervals in that synthesis region.

Functions and Tasks Performed by This Subroutine. This subroutine generates all of the matrices required by this problem except the boundary matrices calculated in the subroutine BCONDS. These matrices are defined in Section II.B by Eqs. 28-30 and 32-38 for the asymmetric interface condition and by Eqs. 28-30, 32-34, and 55-58 for the symmetric interface condition. Each time this routine is called all of the matrices for group C are generated. The matrices are generated a synthesis region at a time, using the partial integrals generated in subroutine PROCES and stored on the data set whose reference number is LPART. The fission and scattering matrices are core-held until they have been generated for all the refined regions in a synthesis region. Then these matrices are written out on the data sets whose reference numbers are IFISS and ISCAT, respectively. The other matrices are kept in core by refined or synthesis region, depending upon their type. The removal matrices (R), boundary condition matrices (C) generated by BCONDS, and the double-gradient inner-product matrices (L) are added together for each refined region and stored in array SIGMAR. Subroutine PROCES generates five types of partial integrals for each Y-direction refined interval $r \in R(k)$ defined below.

$$(1) J_{g'g}^{mn}(k,r) = \int_Y H_{gk}^{*mn} H_{gk}^{mn} dy, \quad r \in R(k),$$

$$(2) J_{g'g}^{mn}(k,r) = \int_Y H_{gk}^{*mn} H_{gk}^{mn} dy, \quad r \in R(k),$$

$$(3) \quad P_{gk}^{mn}(k+1, r) = \int_{\underline{y}}^{\bar{y}} H_{gk}^{*m} H_{gk}^n dy \quad r \in R(k),$$

$$(4) \quad P_{gk}^{mn}(k+1, r) = \int_{\underline{y}}^{\bar{y}} H_{gk}^{*m} H_{gk+1}^n dy \quad r \in R(k),$$

$$(5) \quad Q_{gk}^{mn}(k+1, r) = \int_{\underline{y}}^{\bar{y}} H_{gk}^{*m} H_{gk+1}^n dy \quad r \in R(k+1),$$

where $R(k)$ is the set of Y-direction refined intervals for synthesis region k. For a more detailed description of how these partial integrals are combined to generate the final matrices refer to Section II B.

Notice that when the routine is initialized it checks the data sets LIB ADJT, LIB MIX, LIB PART and LIB REAL for consistency with the problem and each other. Also if the left or right boundary condition is $\varphi = 0$, the corresponding matrix W_{gk} need not be calculated.

d. Subroutines Called by This Subroutine BCNDS, VERBND, (entry in GETBND), ERRMSG, MINV, GMPRD

e. Subroutine Calling This Subroutine SYNGEN

7. Subroutine DIMSCT(SCTLIM, SCTLOC, SCTDIM, CMAX, *)

a. Arguments The first two arguments are defined in common block BLKSTR. The remaining two are defined in common block SINGLE. The asterisk indicates an error return to a specified location in the calling subroutine.

b. Important Local Variables None.

c. Functions and Tasks Performed by This Subroutine This subroutine uses the scattering bandwidths for each composition (set up in array SCTLIM in subroutine RGROUP) to set up in the first CMAX locations of the array SCTLOC the position in an array SCTXS of the final element of the scattering array σ_{gk}^{mn} corresponding to the composition preceding a given composition c(CMPNO).

The position corresponding to the last scattering element for the composition preceding $CMPNO = 1$ is 0, for each succeeding $CMPNO$, the position is $SCTLOC(CMPNO) = SCTLOC(CMPNO-1) + SCTLIM(1, CMPNO-1) + SCTLIM(2, CMPNO-1) + 1$ where $SCTLIM(1, CMPNO-1)$ is the scattering bandwidth corresponding to composition

This subroutine also computes the first dimension SCTDIM of the scattering array SCTXS. This dimension is computed as the position of the final element of composition CMAX-1 SCTLOC(CMAX) plus the bandwidth of the last composition SCTLIM(1,CMAX)+SCTLIM(2,CMAX)+1. In other words, the first dimension of SCTXS is the sum over all compositions of the bandwidths associated with each composition; the second dimension is CMAX. Hence in the scattering array each composition and group is allocated only the maximum bandwidth associated with the composition.

d Subroutines Called by This Subroutine None

e Subroutine Calling This Subroutine RCOMP

8 Subroutine DSRNCK(TIMEKY GMAX JMAX KMAX NGKMX
LMIX LADIT LREAL NN NBP *)

a Arguments The first five arguments are defined in common block SINGLE. The next three arguments are also defined in common block SINGLE, under the names N1, N2, and N3, respectively. The remaining two arguments are defined in common block BLKSTR. The asterisk indicates an error return to a specified location in the calling subroutine.

b Important Local Variables None

c Functions and Tasks Performed by This Subroutine This subroutine checks the three data sets LIB REAL, LIB ADJT, and LIB MIX for consistency. The first word on each data set is a coded key which must be identical for all three data sets; otherwise, execution is terminated immediately. After checking to see that the key is correct, the data set LIB ADJT is read further to see that the three data sets are consistent with this problem. Thus the adjoint trial functions of LIB ADJT must agree in the number of energy groups, the number of points, the number of synthesis regions, and the number of functions per synthesis region and group defined for the problem; otherwise, execution is terminated.

d Subroutine Called by This Subroutine ERRMSG

e Subroutines Calling This Subroutine RDEF PROCES

9 Subroutine DZDCAL(*)

a Arguments The asterisk indicates an error return to a specified location in the calling subroutine.

b Important Local Variables None

c Functions and Tasks Performed by This Subroutine This subroutine exists to call SYNOEN and SYNCAL. Note that this is not a two-dimensional diffusion-theory subroutine.

d Subroutines Called by This Subroutine SYNGEN, SYNCAL

e Subroutine Calling This Subroutine SYN2D

10 Subroutine D2DOUT(*)

a Arguments The asterisk indicates an error return to a specified location in the calling subroutine

b Important Local Variables

<u>Name</u>	<u>Type</u>	<u>Definition</u>
POWBRN	R*8	Normalization factor
POWTOY	R*8	Not used
NERR	I*4	Error flag from LKCELL (boundary condition type incorrect)

c Functions and Tasks Performed by This Subroutine This subroutine is the driver for all output edits. It allocates storage for arrays in the POINTER container array, initializes subroutine arguments, and calls subroutines for output edit. It also causes the reordering of data set FA D2 in the proper manner by group for an adjoint calculation by calling FLOP. (This reordering is not used by the synthesis module.)

d Subroutines Called by This Subroutine IFXVOL, IRGBAL, GETBND, ICPAL, ITOBAL, FLUXPR, ILKCEL, PAGED, IFXNRM, ERRMSG, FLOP.

e Subroutine Calling This Subroutine SYNCAL

11 Subroutine ERRMSG(NAMI, NUM)

a Arguments

<u>Name</u>	<u>Type</u>	<u>Definition</u>
NAMI(2)	R*4	Name of subroutine calling this subroutine (A8)
NUM	I*4	Number assigned to error in subroutine calling this subroutine

b Important Local Variables None

c Functions and Tasks Performed by This Subroutine This subroutine prints the name of the subroutine calling it and the error number assigned to the error which occurred, in the format

ERROR NUMBER and IN SUBROUTINE aaaaaaaa

and return control to calling subroutine. The name is input as an R*4 array of dimension 4 in NAME1 and is set equal to the R*4 array NAME2 which is equivalent to the R*8 member NAME of common block NAMBLK to allow the name to be kept in a common block.

d Subroutines Called by This Subroutine None

e Subroutines Calling This Subroutine BCONDS CALC1 COFGEN DSRNCK D2DOUT GLTCHI IFXVOL IFXNRM IGPCAL ILKCEL IVOL LIB MIGEN1 MTGEN2 PCOMP PROCES RBNDG RCDEF RCOMP RGEOM RGROUP RMESH RSDEF RVEL RXSCOI SINCAL SYNCAL SYNDEF SYNGEN

12 Subroutine FLOP(FLUX POWTOT POWBRN JMAX GMAX)

a Arguments The first argument is defined in common block BLKSTR the last two are defined in common block SINGLE. The remaining arguments are defined below:

<u>Name</u>	<u>Type</u>	<u>Definition</u>
POWTOT	R*8	total adj. dv
POWBRN	R*8	adj. dv

b Important Local Variables

<u>Name</u>	<u>Type</u>	<u>Definition</u>
GA	I*4	Indicates which record to skip to when re-ordering the data set containing the adjoint fluxes for normalization and output as data set FA D2
NFAD2	I*4	Data-set reference number for FA D2

c Functions and Tasks Performed by This Subroutine This subroutine is only called when an adjoint calculation is specified, and it writes FA D2. It takes the latest fluxes from the data set whose reference number is NTH, reorders them in the proper manner by group, normalizes them by POWBRN, and then writes them on FA D2. The references in the subroutine to POWTOT are no longer required. This subroutine is not used by the synthesis module.

d Subroutine Called by This Subroutine SNIFF (ARC System subroutine)

e Subroutine Calling This Subroutine D2DOUT

13. Subroutine FLUXPR(N,Y,CNUM,RNUM,FLUX,P,IMAX,JMAX,G)

a. Arguments The first six arguments are listed in common block BLKSTR. The seventh and eighth are listed in common block SINGLE. The remaining argument indicates which energy group is presently being considered.

b. Important Local Variables

<u>Name</u>	<u>Type</u>	<u>Definition</u>
IPONE	I*4	TWODPR flag for printing rows
JPONE	I*4	TWODPR flag for printing columns
INV	I*4	TWODPR flag for printing out array exactly as stored
PMAX	R*8	Maximum power density
PMIN	R*8	Minimum power density (greater than 0).

c. Functions and Tasks Performed by This Subroutine. This subroutine sets up row and column titles depending upon the geometry type, the heading for the output, and the actual coordinates for each mesh point. It calls subroutine TWODPR to print out the flux array for each energy group and after the last energy group calls subroutine TWODPR to print out the power density by interval. It also picks up and prints out the maximum and minimum nonzero power density and the mesh-cell locations where these occur.

d. Subroutine Called by This Subroutine TWODPR

e. Subroutine Calling This Subroutine. D2DOUT.

14. Subroutine FPRIME KMAX,GMAX,IMAX,NGKMX,NN,DY,HC,HPI

Entry points

Entry: FPRM(HC,H ,G,KNOW)

a. Arguments If first four arguments are defined in common block SINGLE. The arrays NN and DY are defined in common block BLKSTR. The arrays HC and H are defined in common block BLKSTR either as HC and JP or as HADI and HADJP, depending on whether real or adjoint trial functions are being used. All other arguments are listed below

<u>Name</u>	<u>Type</u>	<u>Definition</u>
G	I*4	Present energy group number.
KNOW	I*4	Present synthesis region number.

b. Important Local Variables None

c. Functions and Tasks Performed by This Subroutine This subroutine takes the tabular function values HGI and computes the derivatives HP for each. Note that the array HGI can contain either real or adjoint trial functions. The derivatives H_j are computed as follows

$$H_j = 2(H_{j+1} - H_{j-1}) / (\delta_j + \delta_{j+1}), \quad 1 \leq j < J$$

and

$$H_J = H_{J-1}$$

where δ_j is the length of the jth interval. This subroutine differentiates all the real functions in a synthesis region in one pass. Another call with appropriate substitutions in the calling sequence or FPRM will differentiate the adjoint functions.

d. Subroutines Called by This Subroutine Nonee. Subroutine Calling This Subroutine PROCES15. Subroutine GETBND, BNDC, JBND, C

Entry points

Entry VERBND(IMESH, JMESH, NGRP, DIFCOE, C1, C2, C3, C4, ITYPE)

Entry HORBND(IMESH, JMESH, NGRP, DIFCOE, C1, C2, C3, C4, ITYPE)

a. Arguments The two arguments in the main calling sequence are both references to the array defined in common block BLKSTR as BNDC. The arguments of the entry points are defined below.

<u>Name</u>	<u>Type</u>	<u>Definition</u>
IMESH	I*4	X-direction mesh-line number (negative for left side of line and positive for right side when VERBND is called)
JMESH	I*4	Y-direction mesh-line number (negative for bottom side of mesh line and positive for top side when HORBND is called)
NGRP	I*4	reactant energy-group number
DIFCOE	R*8	diffusion coefficient corresponding to IMESH, JMESH, and NGRP (from DC array)

<u>Name</u>	<u>Type</u>	<u>Definition</u>
C1	R*8	First boundary-condition coefficient
C2	R*8	Second boundary-condition coefficient
C3	R*8	Third boundary-condition coefficient
C4	R*8	Fourth boundary-condition coefficient
ITYPE	I*4	Boundary-condition type (0, 1, 2, or 3).

b. Important Local Variables. None.

c. Functions and Tasks Performed by This Subroutine.

GETBND is the initialization entry. VERBND and HORBND perform the specified functions. VERBND checks through the vertical mesh lines for which boundary conditions have been defined comparing JBND(2,NBC), where NBC = 1, NBCDEF to IMESH. If a match is found the mesh-line numbers in the Y-direction between which the condition applies, JBND(3,NBC) and JBND(4,NBC) and group numbers between which the condition applies, JBND(5,NBC) and JBND(6,NBC), are checked. If JBND(3,NBC) ≤ IMESH ≤ JBND(4,NBC), and if JBND(5,NBC) ≤ NGRP ≤ JBND(6,NBC), the arguments returned are defined as follows.

ITYPE = JBND(7,NBC)

C1 = BNDC(8,NBC)

C2 = BNDC(9,NBC)

C3 = BNDC(10,NBC)

C4 = BNDC(11,NBC)

Further, if ITYPE = 2

C1 = C1 * IFCOE

C3 = C3 * IFCOE

If no match is found, ITYPE and all constants (C1, C2, C3, and C4) are set to zero. The same calculations are performed by HORBND except that JBND(2,NBC) is compared to IMESH and JBND(3,NBC) and JBND(4,NBC) are compared to IMESH for horizontal boundaries.

d. Subroutines Called by This Subroutine. None.

e. Subroutines Calling This Subroutine. GETBND is called by ENI, D2DO, TVEBND, and called by COFGEN, ILKCEL, MTGENI.

HORBND is called by BCONDS, ILKCEL.

16 Subroutine GETCHI:SETCHI:MITRCHI:GMAX:NTAPE)

a Arguments The first argument is defined in common block BLKSTR the next two are found in common block SINGLE. The remaining argument is the data set reference number for XS C MIN.

b Important Local Variables None

c Functions and Tasks Performed by This Subroutine This subroutine reads the set-wide emission spectrum χ^8 8, if one exists from record type 2 of data set XS C MIN.

d Subroutine Called by This Subroutine ERRMSG

e Subroutine Calling This Subroutine RCOMP

17 Subroutine LAPEA(REGMSH,B9Q,REGHHT,X,Y,DX,DY,RMAX,IMAX,JMAX,*)

Entry points:

Entry AREA(AREAL,AREAR,AREAT,AREAB,I,J)

a Arguments The first seven arguments are defined in common block BLKSTR the remaining three appear in common block SINGLE. The asterisk indicates an error return to the calling subroutine. The entry-point arguments are defined below.

<u>Name</u>	<u>Type</u>	<u>Definition</u>
AREAL	R*8	Area on left of cell
AREAR	R*8	Area on right of cell
AREAT	R*8	Area on top of cell
AREAB	R*8	Area on bottom of cell
I	I*4	X-direction mesh-interval number
J	I*4	Y-direction mesh-interval number

b Important Local Variables None

c Functions and Tasks Performed by This Subroutine This subroutine calculates the area and unit height associated with a specified mesh cell (I,J), where A_L is the area on the left, A_R is the area on the right, A_T is the area on the top, and A_B is the area on the bottom.

For XY geometry

$$AR = AL = \Delta Y_j, AT = AB = \Delta X_j$$

For RZ geometry

$$AR = 2-R_{j+1}\Delta Z_j, AL = 2-R_j\Delta Z_j$$

$$AT = AB = -\Delta R_j(2R_j + \Delta R_j)$$

For ZR geometry

$$AR = AL = -\Delta R_j(2R_j + \Delta R_j)$$

$$AT = 2-\Delta Z_{j+1}, AB = 2-\Delta Z_j$$

For RO geometry which is not used by the synthesis module

$$AR = R_{j+1}\Delta O_j, AL = R_j\Delta O_j$$

$$AT = AB = \Delta R_j$$

d Subroutines Called by This Subroutine None

e Subroutines Calling This Subroutine ILKCEL, RGEOM.

18 Subroutine IFXNRM(CMPREG, FSCMP, FISXS, NUFIS, FV, RAF, RV, REGNAM, PR, RMAX, FSCMAX)

Entry points

Entry PLXNRM(POWTOT, POWBRN)

a Arguments. The first nine arguments are defined in common block BLKSTR, the remaining two arguments are defined in common block SINGLE. The two entry-point arguments are listed below

<u>Name</u>	<u>Type</u>	<u>Definition</u>
POWTOT	R*B	$\int \sigma_p d\mathbf{v}$
POWBRN	R*B	$\int \sigma_p d\mathbf{v}$

b Important Local Variables None

c Functions and Tasks Performed by This Subroutine. Entry point IFXNRM is used to initialize the arguments, check geometry type and set up FACT, the normalization factor for data set FR.PN.

Entry point FLXNRM calculates the normalization factor $POWBRN \left(\sum_R \sum_G \sigma_{R,G} \right)$. It normalizes regional flux integrals and region-averaged fluxes for FR PN when applicable. It calculates total power, power and average power by region. Finally, it writes out data set FR PN if required. The power calculations are not performed when the problem is adjoint.

d. Subroutines Called by This Subroutine PAGED, ERRMSG, SNIFF (ARC System Subroutine)

e. Subroutine Calling This Subroutine D2DOUT

19. Subroutine IFXVOL (FV, RV, SV, FIXSRC, REGMSH, FLUX, RMAX, JMAX, IMAX)

Entry points

Entry IFXVOL

a. Arguments The first six arguments are defined in common block BLKSTR, the remaining three appear in common block SINGLE.

b. Important Local Variables None

c. Functions and Tasks Performed by This Subroutine

IFXVOL is an initialization entry which zeroes out arrays for future summations. Entry IFXVOL reads in pointwise fluxes and (if needed) the total fixed source one group at a time. The flux-regional integrals and source-volume integrals are approximated by summation. The region volumes are calculated. The source volume is reordered by group if the problem is adjoint. The reordering makes this data consistent with the structure of D2DOUT.

d. Subroutines Called by This Subroutine ERRMSG, VOL (entry in IVOL).

e. Subroutine Calling This Subroutine D2DOUT

20. Subroutine IGPC (FLUX, P, FIXXS, CMPMSH, FSCMP, FSCMAX, JMAX)

Entry points

Entry GPCAL(G, WTOT, POWBRN, NERR)

a. Arguments First five arguments are defined in common block BLKSTR, the remaining two are defined in common block SINGLE. The entry-point arguments are listed below.

<u>Name</u>	<u>Type</u>	<u>Definition</u>
G	I*4	Present energy-group number
POWTOT	R*8	$\sum \sigma_f \phi dv$
POWBRN	R*8	$\sum \sigma_a \phi dv$
NERR	I*4	Error flag from REGBAL

b. Important Local Variables. None.

c. Functions and Tasks Performed by This Subroutine. Entry point IGPCAL initializes the arguments of the subroutine. It writes the first record of FR.D2 or FA.D2. Finally it zeroes out array P for future accumulations.

Entry point GPCAL reads in fluxes one group at a time, normalizes them with POWBRN (when applicable), and accumulates power density by mesh point. It writes the rest of the records of FR.D2 or FA.D2 and closes the data set. If the KOUT print flag is on, subroutine REGBAL is called.

d. Subroutines Called by This Subroutine. ERRMSG, SNIFF (ARC System-subroutine), REGBAL.

e. Subroutine Calling This Subroutine. D2DOUT

21. Subroutine ILKCEL(CMPMSH,DC,X,DX,Y,DY,FLUX,CMAX,JMAX)

Entry points

Entry. LKCELL(LIJ,JJL,JJR,JJB,JJT,XI,YI,DXI,DYI I,J,G,NERR)

a. Arguments. first seven arrays are defined in common block BLKSTR; the remaining are found in common block SINGLE. The entry-point arguments are listed below.

<u>Name</u>	<u>Type</u>	<u>Definition</u>
LIJ	R*8	Total leakage out of cell (I,J,G)
JJL	R*8	Current across left cell interface
JJR	R*8	Current across right cell interface
JJB	R*8	Current across bottom cell interface
JJT	R*8	Current across top cell interface

<u>Name</u>	<u>Type</u>	<u>Definition</u>
XI	R*8	X-direction coordinate of point (I,J)
YI	R*8	Y-direction coordinate of point (I,J)
DXI	R*8	Mesh interval size in X-direction
DYI	R*8	Mesh interval size in Y-direction
I	I*4	X-direction mesh cell number
J	I*4	Y-direction mesh cell number
G	I*4	Energy group number
NERR	I*4	Error flag for incorrect boundary-condition type

b. Important Local Variables

<u>Name</u>	<u>Type</u>	<u>Definition</u>
AREAL	R*8	Area on left of cell (I,J)
AREAR	R*8	Area on right of cell (I,J)
AREAT	R*8	Area on top of cell (I,J)
AREAB	R*8	Area on bottom of cell (I,J)
DJL	R*8	Gradient ϕ times diffusion coefficient on left
DJR	R*8	Gradient ϕ times diffusion coefficient on right
DJT	R*8	Gradient ϕ times diffusion coefficient on top
DJB	R*8	Gradient ϕ times diffusion coefficient on bottom
DELU	R*8	$(R_{j+1} + R_j) \sin \frac{\Delta\theta_j + \Delta\theta_{j+1}}{4}$ for R0 geometry
WU	R*8	$W_U = \sin(0.5\Delta\theta_{j+1})/\sin(0.5\Delta\theta_j)$ for R0 geometry

c. Functions and Tasks Performed by This Subroutine Entry point LKCEL initializes the arguments passed to this subroutine. For a given geometry point and group (I,J,G), the entry point LKCEL calculates the total leakage (LIT) out of the cell and the neutron currents across each interface of the cell, i.e., top DJT, bottom DJB, left DJL, and right DJR. It also returns the position of the mesh cell (XI,YI) and the mesh interval size (DXI,DYI). NERR is set equal to 1 if a boundary condition type $\neq 2$ is specified. Note that the synthesis module cannot synthesize for R0 geometry.

d. Subroutines Called by This Subroutine AREA, ERRMSG, VERBND (entry in GETBND), HORBND (entry in GETBND).

e. Subroutine Calling This Subroutine D2DOUT.

22. Subroutine IRGBAL(REGMSH, CMPREG, L, RMVL, S, F, T, REM, SCTXS, NUFFIS, CHI, CMPMSH, DC, DX, FLUX, BSQ, SCTLIM, SCTLOC, RV, FSCMP, SV, REGNAM, VEL, JMAX, RMAX, SCTDIM, HIDIM, IMAX, CMAX, FSCMAX)

Entry Points

Entry: REGBAL(G, FLUX, NERR)

a. Arguments The first 23 arguments are defined in common block BLKSTR, the remaining seven are defined in common block SINGLE. The entry-point arguments are listed below.

Name	Type	Definition
G	I*4	Present energy group number
NERR	I*4	Error trace back flag.

b. Important Local Variables

Name	Type	Definition
CL	R*8	Neutron current on left region boundary.
CR	R*8	Neutron current on right region boundary.
CB	R*8	Neutron current on bottom region boundary.
CT	R*8	Neutron current on top region boundary.

c. Functions and Tasks Performed by This Subroutine. Entry point IRGBAL is used to initialize the arguments and to zero out arrays L, RMVL, S, and F for future accumulations.

Entry point REGBAL calculates the contributions to total balance by region and group for leakage (using a call to entry point LKCELL), removal, scattering, and fission. It will also calculate and print neutron currents across region boundaries when the KOUT print flag is 2.

d. Subroutines Called by This Subroutine. LKCELL (entry in ILKCEL), PAGHED.

e. Subroutines Calling This Subroutine. D2DOUT, IGPCAL.

23. Subroutine ITOBAL(LR,RR,SR,FR,TR,SOR,LC,RC,SC,FG,G,
SQG,L,RMVL,S,F,T,NUM,CNUM,FV,SV,RAF,RV,A,RMAX)

Entry points

Entry: TOTBAL

a. Arguments The last argument is listed in common block NGLE, all the previous arguments are defined in common block BLKSTR

b. Important Local Variables

<u>Name</u>	<u>Type</u>	<u>Definition</u>
X	R*8	First used as absorption by region, later as absorption by group
LTOT	R*8	Leakage summed over regions and groups
RTOT	R*8	Removal summed over regions and groups
STOT	R*8	Scattering summed over regions and groups
FTOT	R*8	Fission summed over regions and groups
TTOT	R*8	Balance summed over regions and groups
ATOT	R*8	Absorption summed over regions and groups

c. Functions and Tasks Performed by This Subroutine Entry ITOBAL initializes arguments to the subroutine, zeroes out arrays for future summations, and initializes INV, IPONE, and JPONE.

Entry TOTBAL calls the subroutine TWODPR to print out the arrays FV,RAF,L,RMVL,S,F,T,A and SV

It accumulates each of the above arrays by region and then by group and then sums over both regions and groups. It prints out these summations for all regions and groups

d. Subroutines Called by This Subroutine TWODPR, PAGED.

e. Subroutine Calling This Subroutine D2DOUT.

24. Function IVOL(REGMSH,BSQ,REGHHT,X,Y,DX,DY,RMAX,IMAX,
JMAX)

Entry points

Entry: VOL(I,J)

a. Arguments The first seven arguments are defined in the common block BLKSTR, the remaining three are located in common block SINGLE. The entry-point arguments are listed below.

<u>Name</u>	<u>Type</u>	<u>Definition</u>
I	I*4	X-direction mesh interval number
J	I*4	Y-direction mesh interval number

b. Important Local Variables None.

c. Functions and Tasks Performed by This Function This function calculates the volume per unit height V_{ij} of a specified mesh cell (I,J) according to the reactor geometry type. The initialization call is made to IVOL and calls for the volume value are made to VOL. The volume is computed as follows:

$$\Delta V_{ij} = \Delta X_i \cdot \Delta Y_j \text{ for XY geometry.}$$

$$\Delta V_{ij} = \pi \Delta R_i (\Delta R_i + \Delta R_j) \Delta Z_j \text{ for RZ geometry.}$$

$$\Delta V_{ij} = \pi \Delta R_j (\Delta R_i + \Delta R_j) \Delta Z_i \text{ for RZ geometry.}$$

and

$$\Delta V_i = \frac{4}{3} \pi \Delta R_i \Delta R_j (\Delta R_i + \Delta R_j) \text{ for RS geometry.}$$

Note that RS geometry is not handled by the synthesis module SYN2D.

d. Subroutine Called by This Function ERRMSG.

e. Subroutines Calling This Function RGEOM, IFXVOL, PGEOM.

25. Subroutine LIB(*,GMAX,JMAX,NGKMX,KMAX,ICORE,NN,HQ,LIBFLX,LWHRNO,LWHRSR,IDSNO,IPNT)

a. Arguments The asterisk indicates an error return to a specified location in the calling subroutine. The next four arguments are defined in common block SINGLE. ICORE is a flag passed from ESDEF to indicate if the trial functions used to generate the trial function libraries can be core contained. The remaining arrays are listed in common block BLKSTR.

b. Important Local Variables

<u>Name</u>	<u>Type</u>	<u>Definition</u>
IFLAG	1*4	Trial-function library flag 0 - Working with the trial functions from FR TRIAL 1 - Working with the trial functions from FA TRIAL
LTEST	1*4	Temporarily contains a trial-function number from the user input data sets which are required for this problem
LIBDS1	1*4	Data-set reference number for FR TRIAL
LIBDS2	1*4	Data-set reference number for FA TRIAL

Functions and Tasks Performed by This Subroutine This subroutine generates the problem-dependent trial-function libraries from the user-supplied trial-function libraries. Several different options can be handled, however, the creation of the real and adjoint data sets are similar. First, the real trial functions are read a function at a time for all groups (Refer to the structure of FR TRIAL in Section III E). If the trial functions are core-contained, the needed function for each group is stored in array HG once for each synthesis region in which it is used. When they are not core-held, the needed function for each group G is written on the scratch data set IDSNO(G) once for each synthesis region which uses it.

After all the input trial functions required have been read in the data set LIB REAL is written. When the trial functions are core-held, this is straightforward. When the trial functions are not all core-held, each scratch data set is read, the trial functions for all synthesis regions and one group are core held, and the data set LIB REAL is written. If the adjoints are set equal to the reals the data set LIB ADJT is also written. Finally the data set LIB MIX is written.

When the trial functions are not core-held, each scratch data set is written again with the trial functions that were previously on this data set. The trial functions are then properly ordered on each scratch data set by synthesis region. After all the scratch data sets have been written the second time, they are read again. This time, however, only one record at a time is read from each data set and written on data set LIB MIX. Thus a record is read from the first scratch data set, a record from the second, and so on, until one record from each has been read. Then the process is repeated until all the records have been read. Data set LIB MIX is then complete. Next the adjoint trial function data set is read, and the trial functions are handled in the same fashion, except now the only data set to be written is LIB ADJT. This corresponds to data set LIB REAL in structure and content.

These three data sets are keyed for this problem and must be used together on a problem with the same geometry, the same number of synthesis regions, the same number of trial functions per synthesis region, and the same number of energy groups, otherwise, a terminal error will be encountered by this module.

d. Subroutines Called by This Subroutine. SNIFF (ARC System subroutine), ERRMSG, TLEFT (IBM subroutine)

e. Subroutine Calling This Subroutine RSDEF.

26. Subroutine MADD(A,B,M,N,C)

a. Arguments

<u>Name</u>	<u>Type</u>	<u>Definition</u>
A(M,N)	R*8	See c below.
B(M,N)	R*8	See c below.
M	I*4	First dimension of A, B, and C.
N	I*4	Second dimension of A, B, and C.
C(M,N)	R*8	See c below.

b. Important Local Variables. None.

c. Functions and Tasks Performed by This Subroutine.

Array A is added to array B and the result is stored in array C. Neither A nor B is changed unless the array C is input as the same array as A or B.

d. Subroutines Called by This Subroutine. None.

e. Subroutines Calling This Subroutine. MTGEN1, GALL1, CALC2, SWEEP1, SWEEP2, SINCAL.

27. Subroutine MOVE(A,M,N,B)

a. Arguments

<u>Name</u>	<u>Type</u>	<u>Definition</u>
A(M,N)	R*8	See c below.
M	I*4	First dimension of A and B.
N	I*4	Second dimension of A and B.
B(M,N)	R*8	See c below.

b. Important Local Variables None

c. Functions and Tasks Performed by This Subroutine This subroutine copies the contents of array A into the array B. Array A remains unchanged.

d. Subroutines Called by This Subroutine None

e. Subroutines Calling This Subroutine MTGEN1, CALC1, CALC2, MTGEN2

28. Subroutine MSUB(A,B,M,N,C)

a. Arguments

<u>Name</u>	<u>Type</u>	<u>Definition</u>
A(M,N)	R*8	See c below
B(M,N)	R*8	See c below
M	I*4	First dimension of A, B, and C.
N	I*4	Second dimension of A, B, and C
C(M,N)	R*8	See c below

b. Important Local Variables None

c. Functions and Tasks Performed by This Subroutine This subroutine subtracts array B from array A and stores the results in array C. Arrays A and B remain unchanged by this process unless array C is the same array input as A or B.

d. Subroutines Called by This Subroutine None

e. Subroutine Calling This Subroutine MTGEN2

29. Subroutine MTGEN1(DRRMN,NGKMX,NGKPMX,RRMAX,CMAX,KMAX,IMAX,NN,NNP,SYNMSH,REFREG,NOWMAX,IPLAGS,DX,AMN,BMN,CMN,DMN,KBAR,X,LI,MI,SIGMAR,UNIT,INT,JUNK)

Entry points

Entry: MTGEN1(*,G)

a. Arguments Arguments 2, 7 are located in common block SINGLE. Arguments 1, 8-11, 13-18, 20-24, and 26 are defined in common block BLKSTR, with array REFRREG listed as RR. The remaining calling-sequence arguments and entry-point arguments are listed below.

<u>Name</u>	<u>Type</u>	<u>Definition</u>
NOWMAX	I*4	NOWMAX = NGKMX + NGKPMX
KBAR	I*4	KMAX - 1
IMI	I*4	IMAX - 1
		Error return to calling subroutine.
	I*4	Present energy group number

b Important Local Variables

<u>Name</u>	<u>Type</u>	<u>Definition</u>
FLAG	I*4	Storage check flags 0--Nothing stored in ZMN. 1--Something stored in ZMN
EP	I*4	Synthesis region containing the largest value of ZNORM
IMSHI	I*4	Boundary condition side input to VERBND
IMSH	I*4	X-direction interval corresponding to IMSHI, either the first or last interval
YNORM	R*8	Column norm of $E_{gk}(r)$ computed for each r
XNORM	R*8	Column norm of $D_{gk}(r)$ computed for each r
ZNORM	R*8	A condition number for matrix $D_{gk}(r)$ computed for all r (only the largest is kept as WNORM)
WNORM	R*8	The largest computed condition number
WINT	R*8	δ, r^α which is computed as $DN(I)(X(I) + 0.5DX(I))^{**ALPHA}$

c. Functions and Tasks Performed by This Subroutine. This subroutine is a driver responsible for generating the matrices E , G , and H for each energy group G . The subroutine also returns an estimate of the condition numbers of the matrices $D_{gk}(r)$. Refer to the documentation of the subroutines CALC1 and CALC2 as well as to Section II.B. for more detail on how these matrices are generated. Subroutine GETBND (entry VERBND) is called to obtain the boundary conditions on the reactor left and right. If the geometry type is RZ, the boundary condition on the left is assumed to be $q' = 0$. The matrices E_{IMAX} and $\bar{M}$ are computed here. E_{IMAX} is defined in CALC2; $\bar{M}$ is defined as

$$\bar{M}_i = C_i D_{g1}(1) [C_i D_{gk}(1) + 0.5 C_{i1} W_{g1}]^{-1} W_{g1}$$

If $C_2 = 0$, $\bar{M} = 0$ and the calculation is omitted. If $C_1 = 0$, then $\bar{M} = 2D_{g1}(1)/\delta_1$, where the numbers C_i are from the boundary condition equation $C_1\psi + C_2\psi' = C_3 - C_4$ should be identically zero in all cases. The matrix $\bar{M}$, if computed, is stored in array BLK(1:ZMN). Finally, after all other matrices have been generated, δ_{IMAX} is calculated. For this calculation, $R^0 M_{\text{IMAX}}$ is required where $R^0 = X(\text{IMAX}+1)^{\text{**}}\text{ALPHA}$ and $D_{g1}(1)$, W_{g1} , and δ are replaced by $D_{gk}(\bar{r})$, W_{gk} , and δ_{IMAX} , respectively. Note K is the last synthesis region, and $\bar{r}$ is the last refined region in synthesis region K . Finally, a check is made to see if anything was stored in ZMN by this subroutine. Anything stored is then added to E_1 .

d. Subroutines Called by This Subroutine. CALC1, CALC2, NORM, MINV, MOVE, GMPRD, GETBND, NUMMLT, MADD, ERRMSG.

e. Subroutine Calling This Subroutine SYNGEN

10. Subroutine MTGEN2(IHINT, GINT, IINT, WORK, AREA, LI, MI, NN, IMAX, GMAX, KMAX, SYNMSH, NGKMX, IM1, SPACE)

Entry points

Entry MTGEN2(G,*)

a. Arguments. Arguments 1-8, 12, and 15 are located in common block BLKSTR; arguments 9-11 and 13 appear in common block SINGLE. The remaining arguments are defined below.

<u>Name</u>	<u>Type</u>	<u>Definition</u>
IM1	I*4	IMAX-1
G	I*4	Present energy group number
Z	-	Error return to calling subroutine

b. Important Local Variables

<u>Name</u>	<u>Type</u>	<u>Definition</u>
K	I*4	Synthesis region in which interval l lies.
NGK	I*4	Number of trial functions per synthesis region K .
DET	R*8	Determinant (U^{-1}) (checks to see if U^{-1} exists).
KPI	I*4	Synthesis region in which the $(l+1)$ th interval lies.
KMI	I*4	Synthesis region in which the $(l-1)$ th interval lies.

Name	Type	Definition
NGKI	1*4	Number of trial functions for synthesis region KPI.
NGKMI	1*4	Number of trial functions for synthesis region KMI.

c Functions and Tasks Performed by This Subroutine. This subroutine factors the tridiagonal matrix P_g (whose elements are matrices).

(1) $P_g = LU$, where L is the lower triangular, U is the upper triangular.

$$(2) \quad P_g = \begin{bmatrix} E_1 & -G_1 & 0 & \dots & 0 \\ -H_2 & E_2 & -G_2 & \dots & 0 \\ & & & E_{l-1} & -G_{l-1} \\ 0 & 0 & 0 & -H_l & E_l \end{bmatrix}$$

$$(3) \quad L = \begin{bmatrix} U_1 & 0 & \dots & 0 \\ -H_2 & U_2 & \dots & 0 \\ & & & & \\ 0 & 0 & -H_l & U_l \end{bmatrix} \quad U = \begin{bmatrix} ID & -V_1 & \dots & 0 \\ & ID & & \\ & & & -V_{l-1} \\ 0 & & & ID \end{bmatrix}$$

where ID is the identity matrix and

$$(4a) \quad U_1^{-1} = E_1^{-1}, \quad V_1 = U_1^{-1} G_1.$$

$$(4b) \quad U_i^{-1} = (E_i - H_i V_{i-1})^{-1}, \quad V_i = U_i^{-1} G_i.$$

$$2 \leq i \leq l_{MAX} \text{ with } G_{l_{MAX}} = 0.$$

The dimensions of the matrices are

$$(5) \quad U_i \text{ and } E_i, \quad N_i \times N_i.$$

$$H_i, \quad N_i \times N_{i-1}.$$

$$G_i \text{ and } V_i, \quad N_i \times N_{i+1}.$$

where N_i is the number of trial functions used in the synthesis region in which interval i lies.

Since only IM1 H_i matrices exist, they are packed upward in array HINT. The subroutine calculates the matrices U_i^{-1} and V_i and writes them out on the data set whose reference number is JLIB. The matrices H_i are written out on the data set whose reference number is NLIB.

Notice that upon entering the subroutine, the matrices E_i , H_i , and G_i are stored in arrays UINT, HINT, and GINT, respectively while upon termination of the subroutine, U_i^{-1} and V_i replace E_i and G_i respectively, in storage. This subroutine is called once for each group.

d. Subroutines Called by This Subroutine MINV, ERRMSG, MOVE GMPRD, MSUB

e. Subroutine Calling This Subroutine SYNGEN

31. Subroutine NORM(ARRAY,N,ANORM)

a. Arguments

<u>Name</u>	<u>Type</u>	<u>Definition</u>
ARRAY(N,N)	R*8	The square matrix whose column norm we wish to know.
N	I*4	Number of columns and rows in ARRAY
ANORM	R*8	Column norm returned by the routine.

b. Important Local Variables

<u>Name</u>	<u>Type</u>	<u>Definition</u>
ZNORM	R*8	Intermediate sum of the absolute values of a column.

c. Functions and Tasks Performed by This Subroutine. This subroutine finds a norm of a square matrix array by obtaining $ANORM = \max(ZNORM_i \text{ for } i = 1, \dots, N)$, where $ZNORM_i$ is sum of the absolute values of the elements of the i th column.

d. Subroutines Called by This Subroutine None.

e. Subroutines Calling This Subroutine MTGEN1, CALCI.

32. Subroutine NUMMLT(X M N A B)a. Arguments

<u>Name</u>	<u>Type</u>	<u>Definition</u>
X	R*8	See c below
M	I*4	First dimension of A and B.
N	I*4	Second dimension of A and B.
A(M,N)	R*8	See c below.
B(M,N)	R*8	See c below.

b. Important Local Variables None.

c. Functions and Tasks Performed by This Subroutine. This subroutine multiplies array A by X and stores the result in array B. Both X and array A remain unchanged; unless the same array is input as both A and B.

d. Subroutines Called by This Subroutine None.

e. Subroutines Calling This Subroutine. CALC2, CALC1, MTGEN!, SINCAL.

33. Subroutine PAGHEDa. Arguments Noneb. Important Local Variables. None.

c. Functions and Tasks Performed by This Subroutine. This subroutine updates the page number and prints a page heading and the number from the common block HEADER at the top of a page. The page heading must have been initialized and the page number set to zero before the first call to this subroutine.

d. Subroutines Called by This Subroutine None.

e. Subroutines Calling This Subroutine. TWODPR, D2DOUT, IEXNRM, IRGBAL, ITOBAL, PCOMP, PGEOM, PRTEC, RCDEF, RSDEF, RVEL, SINCAL.

34. Subroutine PCKSCT(SCTLIM,SCTLOC,SCTDUM,SCTXS,CMAX,DUMDIM,SCTDIM,GMAX,*)

a. Arguments. The first four arrays are located in common block BLKSTR. DUMDIM, defined as CMAX*GMAX, is the first dimension

of array SCTDUM. The remaining arguments are listed in common block SINGLE. The asterisk indicates an error return to the calling subroutine.

b. Important Local Variables

<u>Name</u>	<u>Type</u>	<u>Definition</u>
ML	I*4	Lowest-numbered group from which down-scattering into group G can occur for a given composition C, according to number of down-scattering groups in G.
MU	I*4	Highest-numbered group from which upscattering into given group G can occur for a given composition C, according to number of upscattering groups in G.
HLIM1	I*4	Lower limit of group number from which down-scattering into group G can occur for a given composition C ($\max(1, ML)$)
HLIM2	I*4	Upper limit of group number from which up-scattering into group G can occur for a given composition C ($\min(GMAX, MU)$)
GSUB1	I*4	Position of desired scattering element $\sigma_c^{g \rightarrow g}$ in array SCTXS
GSUB2	I*4	Position of desired scattering element $\sigma_c^{g \rightarrow g}$ in array SCTDUM.

c. Functions and Tasks Performed by This Subroutine. This subroutine packs the scattering data from the SCTDUM array, dimensioned $(CMAX*GMAX*GMAX)$ into which the data was read from data set XS.C.MIN, into the SCTXS array, dimensioned $(GMAX * \sum_{C=1}^{GMAX} SCTLIM(1,C) + SCTLIM(2,C) + 1)$, where $SCTLIM(1,C) + SCTLIM(2,C) + 1$ is the maximum bandwidth associated with a given composition C.

At the beginning of this subroutine, the first CMAX locations of the array SCTLOC contain the locations of the last position assigned in SCTXS to the preceding composition; in other words, $SCTLOC(CMPNO, 1) + 1$ is the location of the first position in SCTXS assigned to composition CMPNO.

By the end of the subroutine, SCTLOC will contain a reference to the first element of the band of groups H from which scattering occurs into a given group G for a given composition CMPNO. Hence, the array SCTXS is "packed" from $G = GMAX$ to $G = 1$ in descending order by groups, so that the first CMAX locations of SCTLOC, used in the packing procedure, will not be destroyed until the final pass.

The packing is accomplished as follows. For a given composition CMPNO and group G, the number ML of the lowest-numbered group from which downscattering could occur is found by subtracting the maximum number of downscattering groups associated with the composition (SCTLIM(1,CMPNO)) from the group number G. Since this number could be negative, the lower limit HLIM1 of the actual possible scattering band for this group G is then computed as $\max(1, ML)$. Similarly, the number MU of the highest-numbered group from which upscattering into group G could occur is found by adding SCTLIM(2,CMPNO) to G. Since this number could be greater than GMAX, the upper limit HLIM2 of the possible scattering band for this group G is then computed as $\min(GMAX, MU)$.

The scattering location SCTLOC(CMPNO,G) associated with the band for that composition and group is then computed as the sum of the first location in SCTXS assigned to the composition, CMPNO, and the difference between the number of possible downscattering groups in the composition and the group number G: $SCTLOC(CMPNO,G) = (SCTLOC(CMPNO,1) + SCTLIM(1,CMPNO) - G)$. This number may be negative, it corresponds to ML plus the location of scattering elements associated with the composition.

Finally, using the limits set up from $H = HLIM1$, $HLIM2$, the elements of the scattering band associated with CMPNO and G are packed. The scattering element $\sigma_{CMPNO, H \rightarrow G}$ is fetched from SCTDUM(GSUB2,G), where GSUB2 is simply $(CMPNO-1)*GMAX+H$, and stored in SCTXS(GSUB1,G), where GSUB1 is $SCTLOC(CMPNO,G)+H$.

Fig. 5. Bandwidth Structure

Although a full bandwidth $SCTLIM(1,CMPNO) + SCTLIM(2,CMPNO) + 1$ is allocated for use by each group G in the composition, then, only the elements actually present for that group G are actually stored or fetched. The other locations are not used. This can be seen in Fig. 5; for a given composition CMPNO, the array SCTDUM looks like $GMAX * GMAX$ square in the diagram, where the white area represents the maximum bandwidth associated with the composition.

All the elements in the parallelogram are stored as a rectangle which is GMAX long and the bandwidth wide in the array SCTXS, but only the elements of the parallelogram that all within the larger square actually exist and are referenced for a given group G.

- d. Subroutine's Call d b This Subroutine. None.
- e. Subroutine Calling This Subroutine. RCOMP.

35. Subroutine PCOMP(DC REM, FSCMP, FISXS, NUFIS, CHI, SCTLIM, SCTLOC, SCTXS, CMPNAM, CMAX, FSCMAX, CHIDIM, SCTDIM, GMAX, IERR, *)

a. Arguments. The first 10 arguments are listed in common block BLKSTR; the next five are listed in common block SINGLE. The flag IERR and the asterisk are defined below.

<u>Name</u>	<u>Type</u>	<u>Definition</u>
IERR	I*4	Error flag (input from search module). = 0--No error. ≠ 0--A given cross section has been made negative during concentration search (not possible in SYN2D).
*		Error return to calling subroutine if IERR > 0.

b. Important Local Variables

<u>Name</u>	<u>Type</u>	<u>Definition</u>
AB(6)	R*8	Cross-section data names corresponding to IERR flag values.
CLIM1	I*4	Lower limit of fission-spectrum values χ_g^g for given fissionable composition c and group g for χ -matrix in array CHI.
SLIM1	I*4	Lower limit of scattering band σ_c^g for given composition c and group g in array SCTXS.
SLIM2	I*4	Upper limit of scattering band σ_c^g for given composition c and group g in array SCTXS.

c. Functions and Tasks Performed by This Subroutine. This subroutine prints cross-section data by composition, as read from data set XS, C-MIN and modified for use by the two-dimensional synthesis and diffusion modules.

Data printed for a nonfissionable composition are simply the composition name and the group number and diffusion coefficient and removal cross section for each group, followed by a table containing the scattering cross section.

For a fissionable composition, the composition name is followed by the group number, diffusion coefficient, removal cross section, nu times fission cross section, fission-spectrum cross section, if present as a vector, and fission cross section. If the fission spectrum is a matrix, it is printed in a separate table and in either case the scattering cross section is printed in the last table for that composition.

The IERR flag must be set to zero before calling this subroutine from any subroutine other than the two-dimensional diffusion search driver, or return may be made to the calling subroutine through the first return provided in the calling sequence.

d. Subroutines Called by This Subroutine. PAGHED, ERRMSG.

e. Subroutine Calling This Subroutine. RCOMP.

36. Subroutine PGEOM(X,DX,Y,DY,BSQ,REGHHT,REGMSH,
CMPMSH,CMPREG,IMAX,JMAX,RMAX)

a. Arguments. The first nine arguments are defined in common block BLKSTR; the remaining three are listed in common block SINGLE.

b. Important Local Variables

<u>Name</u>	<u>Type</u>	<u>Definition</u>
VLM	R*8	Volume of a mesh cell (from function VOL).

c. Functions and Tasks Performed by This Subroutine. This subroutine prints geometry data, as read from data set GEOM and modified for use by the two-dimensional diffusion and synthesis modules. It first prints the name of the geometry type.

Second, it prints a table of mesh-dependent data, consisting of mesh-line locations (X,Y), mesh-interval numbers, mesh-interval lengths (DX,DY), mesh-interval volumes per unit height (function VOL), and the numbers of the region and the composition corresponding to the interval.

Finally, if the geometry is not RZ or ZR, a table of region-dependent data is printed, consisting of the region number, the corresponding composition number, the buckling B^2 (BSQ) in the region, and the actual half-height (H_L) (REGHHT) of the region.

d. Subroutines Called by This Subroutine. PAGHED, VOL (entry in IVOL).

e. Subroutine Calling This Subroutine. RGEOM.

37. Subroutine PROCES(LMIX,LREAL,LADJT,LPART,JMAX,
NGKMX,GMAX,KMAX,NAB,RESULT,HC,HADJG,NN,NBP,HP,
HADJP,DY,NUMRRJ,RRJLOC,RRFJ,Y,TIMEKY,*)

a. Arguments. The first eight arguments and the last argument are defined in common block SINGLE with LMIX, LREAL, and LADJT

listed as N3, N1, and N2, respectively. The variable NAB is defined as the sum of NALPHA and NBETA, which are defined in common block SINGLE. The remaining arguments are defined in common block BLKSTR. The asterisk indicates an error return to the calling subroutine.

b. Important Local Variables

<u>Name</u>	<u>Type</u>	<u>Definition</u>
LPNT	I*4	Location in arrays HADJG and HADJP where the adjoint trial functions and derivatives for synthesis region K and energy group LG are stored.
NPNT	I*4	Location in arrays HADJG and HADJP where the adjoint trial functions and derivatives for synthesis region K - 1 and energy group LG are stored.
IPNT	I*4	Location in arrays HG and HP where the real trial functions and derivatives for synthesis region K and energy group G are stored.
JPNT	I*4	Location in arrays HG and HP where the real trial functions and derivatives for synthesis region K - 1 and energy group LG are stored.

c. Functions and Tasks Performed by This Subroutine. This subroutine is the driver for the partial integral generation and the calculation of the trial functions at the boundaries of the reactor. Five different types of partial integrals are calculated. Refer to Section II-B. for a more detailed description of the partial integrals. Due to storage requirements, all required trial functions cannot be held in core at the same time. The method of generating these partial integrals is also dependent upon the order in which the resultant matrices are used in the iteration section of the code. With these restrictions in mind, the partial integrals are generated and the I/O handled in the following manner. The adjoints for energy group g and synthesis region k are read in, and their derivatives calculated. The real trial functions for synthesis region k, energy group $g' = 1$ are then read in, and their derivatives calculated. The partial integrals of their products are then calculated. If $g' = g$, the partial integrals of the products of the derivatives are also calculated. Both integrations are performed in synthesis region k. Finally, if $k > 1$, with g' still equal to g, the last three partial integral sets are created. Note that the trial functions for the $(k - 1)$ st synthesis region were stored previously. Next, the values of IPNT and JPNT are interchanged and g' is increased by 1. When $g' = GMAX$, the real trial functions for the next synthesis region $k + 1$ and energy group $g' = 1$ are read, while the adjoints for the new synthesis region are also read. When $k = KMAX$, g is advanced by 1 and the process starts again. Note that the values of LPNT and NPNT are interchanged whenever the adjoint trial functions are read, but the values of IPNT and JPNT are only

changed when $g' = g$. Finally, the calculated partial integrals are written in subroutine RIEMAN, and the values of the trial functions at the boundaries are written in subroutine VALUES.

d. Subroutines Called by This Subroutine. SNIFF (ARC System subroutine), ERRMSG, DSRNCK, RIEMAN, FPRIME, VALUES and CLOSE.

e. Subroutine Calling This Subroutine. RSDEF.

38. Subroutine PRTBC(X,Y,BNDC,JBND,NV,NH,*)

a. Arguments. The first four arguments are defined in common block BLKSTR, and BNDC and JBND both refer to the array named BNDC. The remaining arguments are listed below.

<u>Name</u>	<u>Type</u>	<u>Definition</u>
NV	I*4	Number of vertical boundary conditions given.
NH	I*4	Number of horizontal boundary conditions given.
*		Error return to calling subroutine.

b. Important Local Variables

<u>Name</u>	<u>Type</u>	<u>Definition</u>
IP	I*4	Flag indicating inhomogeneous boundary conditions are defined.

c. Action and Tasks Performed by This Subroutine. This subroutine checks to see if any boundary conditions defined are inhomogeneous. If any are found to be, it makes the IP flag nonzero.

The subroutine prints the boundary condition data and then checks the calculation type and the IP flag. If any inhomogeneous boundary conditions appear and the calculation is not a source calculation, an error is flagged. The (*) in the calling sequence is an error return.

d. Subroutine Called by This Subroutine. PAGED.

e. Subroutine Calling This Subroutine. RBND.

39. Subroutine RBND(*)

a. Arguments. asterisk indicates an error return to calling subroutine.

b. Important Local Variables.

<u>Name</u>	<u>Type</u>	<u>Definition</u>
NTAPE	I*4	Data set reference number of BC.
ITYPEL	I*4	Boundary condition type on left reactor boundary.
ITYPER	I*4	Boundary condition type on right reactor boundary.
IBNDC	I*4	Location of BNDC array in BLK.
IX	I*4	Location of X array in BLK.
IY	I*4	Location of Y array in BLK.
NVBND	I*4	Number of vertical boundary conditions defined.
NHBND	I*4	Number of horizontal boundary conditions defined.
ITYPEB	I*4	Boundary condition type at bottom of reactor.
ITYPET	I*4	Boundary condition type at top of reactor.
NVBND1	I*4	NVBND + 1.
CDUM(4)	R*8	Boundary condition coefficients as read from BC (stored in R*4 array C).

c. Functions and Tasks Performed by This Subroutine. This subroutine controls the reading of the boundary and interface condition data from data set BC.

The first record of BC gives the boundary condition types at the left, right, bottom and top boundaries, which are ignored, and the numbers NVBND and NHBND, i.e., the number of boundary and interface conditions defined in the succeeding records of the data set.

The subroutine reads the contents of each succeeding record and stores each in the common block BCBLK. For each, it then calls STORBC to store the data in the BNDC array before reading the next record.

This subroutine then calls PRTBC to print the boundary condition data from the BNDC array, if desired, and to check for consistency of boundary condition type with the calculation type.

d. Subroutine Called by This Subroutine. SNIFF (ARC System subroutine), ERR, S O C, RTBC.

e. Subroutine in This Subroutine. SYNIN.

40. Subroutine RCDEP(*)

a. Arguments. The asterisk represents an error return to the calling subroutine.

b. Important Local Variables. None.

c. Functions and Tasks Performed by This Subroutine. This subroutine reads in the first three card types of the module-dependent data from data set A.SYN2D. The data are stored in the common blocks SINGLE and HEADER for later reference. Default options are supplied when necessary for some of the input parameters. The remaining user-supplied data on data set A.SYN2D are read later in subroutines SYNDEF and LIB. Finally, the container array BLK, used by the dynamic storage routine POINTR, is allocated and the scratch-data-set reference numbers are determined.

d. Subroutines Called by This Subroutine. SNLFF (ARC System subroutine), ERRMSG, PAGHED, POINTR (ARC System subroutine), BULK (entry in POINTR).

e. Subroutine Calling This Subroutine. SYNIN.

41. Subroutine RCOMP(*)

a. Arguments. The asterisk represents an error return to the calling subroutine.

b. Important Local Variables

<u>Name</u>	<u>Type</u>	<u>Definition</u>
NTAPE	I*4	Data-set reference number for XS.C.MIN.
ISCH	I*4	Set-wide fission spectrum. 0--No set-wide X. 1--Set vector. GMAX--Set X-matrix.
NTAPE1	I*4	Data-set reference number XS.DELAY.
IERR	I*4	Error flag set to zero before calling RCOMP.

c. Functions Task Performed This Subroutine. This subroutine controls the read of position- and group-dependent data from XS.C.MIN, XS.DELAY, and XS.SQ.

The first thing read is the first record of XS.C.MIN and the end-of-file following that record. If a set-wide fission spectrum is

is present, the MTRCHI flag is set for a χ -vector or χ -matrix, accordingly, and GETCHI is called to read the set-wide χ from the second record of XS.C MIN. If no set-wide χ is present, MTRCHI is set up for a matrix temporarily. (SYN2D handles only χ -vectors.)

Space for storage of arrays is then allocated, and RDELAY is called to read delayed data from XS.DELAY if the kinetics option is 2. (SYN2D has no kinetics option.) Following this, the CMAX composition blocks of XS.C MIN are read by calling RGROUP once for each composition.

The subroutine then sets up scattering-band positions in the scattering array and packs the scattering array by calling DIMSCT and PCKSCT. If a print of composition data is desired (KOUT $\neq$ 0), PCOMP is then called, and finally RVEL is called to read the neutron speeds, required from data set XS.ISQ. (Neutron speeds are not used by SYN2D.)

d. Subroutines Called by This Subroutine. SNIFF (ARC System subroutine), ERRMSG, GETCHI, RDELAY, RGROUP, DIMSCT, PCKSCT, PCOMP, RVEL, RXSCOL.

e. Subroutine Calling This Subroutine. SYNIN.

42. Subroutine RDELAY(DEC CON, DICHI, NFAM, GMAX, NTAPE, *)

a. Arguments. The first two arguments are defined in common block BLKSTR; the next two are found in common block SINGLE; NTAPE is the data-set reference number for XS.DELAY. The asterisk represents an error return to the calling subroutine.

b. Important Local Variables. None.

c. Functions and Tasks Performed by This Subroutine. This subroutine reads delayed data for kinetics options 1 or 2 from data set XS.DELAY. It skips the first three records and reads the decay constants (DEC CON) from the fourth record and the delayed-neutron spectrum (DICHI) from the fifth. (Delayed data are not required by the SYN2D module.)

d. Subroutines Called by This Subroutine. None.

e. Subroutine Calling This Subroutine. RCOMP.

43. Subroutine RGEO (*)

a. Arguments. The asterisk represents an error return to a specified statement number in the calling subroutine.

b. Important Local Variables

<u>Name</u>	<u>Type</u>	<u>Definition</u>
NTAPE	I*4	Data set reference number for GEOM.
LAREA	I*4	Length of area record (record 06 of GEOM).
LZONE	I*4	Length of zone record (record 07 of GEOM).
NFIN	I*4	Number of finite geometry type.
NIL	I*4	Number of finite directions.

c. Functions and Tasks Performed by This Subroutine. This subroutine reads geometry data from data set GEOM and modifies it for use by the two-dimensional diffusion and synthesis modules. Only record 1 is actually read within RGEOM; record types 2-9 are read in RMESH.

RGEOM modifies the geometry type NGEOM read from data set SP.CICN, which should be the same as that read from GEOM, so that its possible values are 1, 2, 3, or 4. (The geometry type is read from SP.CICN so that any change made to a type 03 card in A.NIP during a MODIFY will be found in SP.CICN; hence, if GEOM is not being modified by any other card type, it can remain an old data set.)

The space needed for geometry-related arrays is then allocated, and RMESH is called to read record types 2-9 and modify the contents appropriately. IVOL and IAREA are initialized; and the geometry-related data are printed by PGEOM if the output option flag KOUT is greater than zero.

d. Subroutines Called by This Subroutine. SNIFF (ARC System subroutine), RMESH, PGEOM, ERRMSG.

e. Subroutine Calling This Subroutine. SYNIN.

44. Subroutine RGROUP(DC, REM, FSCMP, NUFIS, CHI, DNSCT, UPST, ISCT, LIM, SCTXS, SETCHI, DECCON, DICHI, DCCHI, FISXS, CMPNAM, BLKCM, BLKGRP, CMAX, FSCMAX, CHIDIM, NEAM, ISCHI, SCTDIM, NFS, MP, CMPNO, NBLACK, NTAPE, *)

a. Arguments. The first 17 arguments are defined in common block BLKSTR; arguments 18- 1, 23, and 26 can be found in common block SINGLE. The remaining arguments are described below.

<u>Name</u>	<u>Type</u>	<u>Definition</u>
ISCHI	I*4	Set chi flag. 0- o set-wide x. 1- Set-wide x-vector. G AX--Set-wide x-matrix.

<u>Name</u>	<u>Type</u>	<u>Definition</u>
NFSCMP	I*4	Index of this composition in arrays of fissionable data
CMPNO	I*4	Number of this composition.
NTAPE	I*4	Data-set reference number for XS.C.MIN.
*	-	Error return to calling subroutine.

b. Important Local Variables

<u>Name</u>	<u>Type</u>	<u>Definition</u>
ICHI	I*4	Fission-spectrum flag for this composition. - 1-- Uses set χ . 0-- Nonfissionable. 1-- Uses own χ -vector. GMAX-- Uses own χ -matrix.
CLIM1	I*4	Position of first element of fission spectrum for this composition in array CHI.
CLIM2	I*4	Position of last element of fission spectrum for this composition in array CHI.
NB	I*4	Black composition flag: 0-- This composition not defined as black. 1-- This composition defined as black for some group or groups.
SCTDN	I*4	Number of groups of downscattering for given group in this composition.
SCTUP	I*4	Number of groups of upscattering for given group in this composition.
SLIM1	I*4	Position of first element of scattering cross section for given group in dummy array.
SLIM2	I*4	Position of last element of scattering cross section for given group in dummy array.
IH	I*4	Position of Hth element in scattering array for given group G.
IK	I*4	Position of Kth element in scattering array for given group G.
DUMSCT	R*8	Dummy variable used in flipping positions of scattering-array elements for given group.
G	I*4	Pos of Gth (self-scattering) element in scattering array for given group G.

<u>Name</u>	<u>Type</u>	<u>Definition</u>
SUM	R*8	Sum of delayed data over families to be added to fission spectrum.
GSUB	I*4	Scattering-array index.

c Functions and Tasks Performed by This Subroutine. This subroutine reads a composition block from XS C.MIN for all groups G of a given composition CMPNO and modifies the data for use by all diffusion modules.

RGROUP first reads the initial record of the composition block containing the fission-spectrum flag ICHI and the number of up-scattering and downscattering groups defined for each group, UPSCT and DNSCT. Using the fission-spectrum flag, the locations for the fission-spectrum elements for this composition are set aside in the array CHI if any are needed. Elements for this composition are then all set to zero.

Next, the subroutine checks to see if this composition is black for any groups, by comparing this composition name with those defined as black (BLKGMP). If any match is found, a flag NB is set, and the group limits for that composition are set up in BLKGRP, if either or both is zero. If the first group limit is zero, the limits are set to 1 and GMAX, if the first is nonzero and the second is zero, the second is set to the first, so that the condition applies to only one group. The composition name is compared to all compositions defined as black, even after a match is found, so that group limits will be made uniform for all occurrences of definition of this composition as a black composition. (A composition name might appear more than once if it were defined as black for two or more noncontiguous sets of groups, e.g., for G = 1 to 7 and for G = 16.) Black composition data are not defined for SYN2D.

The subroutine then begins to perform a series of tasks for each group in this composition. It sets up the locations in the scattering array assigned to the band associated with this composition and group (SLIM1, SLIM2), and also the maximum scattering bandwidth which will be associated with the scattering for this composition after the data have been packed, defined by $SCTLIM(1, CMPNO) + SCTLIM(2, CMPNO) + 1$. Here $SCTLIM(1, CMPNO)$ is the maximum number of groups of downscattering, and $SCTLIM(2, CMPNO)$ is the maximum number of groups of upscattering.

The cross-section data for this composition and group are then read according to the proper format, depending on whether the composition is fissionable or nonfissionable, on whether the fission spectrum is present as a matrix or vector or the set-wide χ is used, and on whether delayed data for an alpha calculation are to be read. If the set-wide fission spectrum is to be used for this composition, the fission spectrum for this composition and group in the array CHI is set equal to the set-wide χ from the array SETCHI.

The diffusion coefficient for this composition and group is then set up using the transport coefficient. $D_{c,g} = 1/(3\sigma_{TR})$, unless $\sigma_{TR} = 0$, in which case $D_{c,g}$ is set to $1.0E+15$. Then, if this composition was defined as black over any group or groups, the subroutine checks to see if this group is between the group limits. If it is, the diffusion coefficient $D_{c,g}$ is set to zero.

The subroutine then reverses the order of the elements in the scattering array for this composition and group, since they are read in order from the scattering from highest-number group into g through scattering from the lowest-number group into g and are stored in the opposite order, and then sets the self-scattering term to zero. This completes the list of tasks performed for each group for this composition.

Finally, if delayed data for an alpha calculation is present, the delayed fission-spectrum terms are added into the fission-spectrum array CHI.

d. Subroutine Called by This Subroutine. ERRMSG.

e. Subroutine Calling This Subroutine. RCOMP.

45. Subroutine RIEMAN(DY, RESULT, Y, NUMRRJ, RRFJ, HP, HADJP, HG, HADJG, RRJLOC, NAB, JMAX, NGKMX, LPART)

Entry points

Entry: RIEHAT(NREAL, K, HP, HADJP)

Entry: RIEINT(NREAL, NADJT, K, HG, HP, HADJG, HADJP)

a. Arguments. The first nine arguments of the main calling sequence are defined in common block BLKSTR; the last three arguments are defined in common block SINGLE. The remaining arguments are defined below.

<u>Name</u>	<u>Type</u>	<u>Definition</u>
NAB	I*4	N LPHA + NBETA (refer to common block SINGLE).
NREAL	I*4	T number of real trial functions in array HG.
K	I*4	Present synthesis region number.
NADJT	I*4	Th number of adjoint trial functions in array JG.

b. Important Local Variables

<u>Name</u>	<u>Type</u>	<u>Definition</u>
NUMBER	I*4	The number of Y-direction refined intervals in synthesis region K.
IPOINT	I*4	Location in array RRFJ where the first Y-direction refined interval number is stored.
J1	I*4	First interval of the Y-direction refined region L.
J2	I*4	Last interval of the Y-direction refined region L.
A1	R*8	The leading coefficient of $H_n = A_1y + A_2$.
A2	R*8	The second coefficient of $H_n = A_1y + A_2$.
B1	R*8	The leading coefficient of $H_m^* = B_1y + B_2$.
B2	R*8	The second coefficient of $H_m^* = B_1y + B_2$.
A	R*8	The leading coefficient of the combined product polynomial.
B	R*8	The second coefficient of the combined product polynomial.
C	R*8	The last coefficient of the combined product polynomial.
XY	R*8	$\hat{y}_{j+1} - \hat{y}_j$, where $\hat{y}_{j+1}$ and $\hat{y}_j$ are the upper and lower limits of integration.
XPY	R*8	$\hat{y}_{j+1} + \hat{y}_j$, with the above comment applying.
XY	R*8	$\hat{y}_j \hat{y}_{j+1}$, with the above comment applying.

c. c ons and Tas s Perform d. brdu n. This subroutine performs all the integrations prob m requires. he two different types of integrals generated are

$$a) J_{(r_1)}^{mn} = \int_{y_{1-1}}^{y_1} H_m^*(y) H_n(y) -NAB \, dy \quad 1 \leq m \leq NREAL$$

and

$$b) J_{(r_1)}^{mn} = \int_{y_{1-1}}^{y_1} H_m^*(y) H_n(y) -NAB \, dy \quad \begin{matrix} 1 \leq m \leq NABIT \\ 1 \leq n \leq NREAL \end{matrix}$$

where NAB is either 0 or 1, depending upon geometry, r_i is the i th Y-direction refined interval in synthesis region K, and y_q are the mesh cell boundaries. The partial integrals J and I are calculated by entry points RIEHAT and RIEINT, respectively. Refer to Section II.B and II.C as well as to the documentation of subroutine RRCALC for the definition of partial integrals and Y-direction refined intervals.

The partial integral $J_{(r_i)}^{mn}$ when NAB is zero is approximated by

$$J_{(r_i)}^{mn} = \sum_{j=l}^{\bar{l}} \frac{1}{2} \delta_j \left[H_m^{*'}(y_j) H_n'(y_j) + H_m^{*'}(y_{j-1}) H_n'(y_{j-1}) \right],$$

where δ_j is the length of the Y-direction interval j and the intervals j are all the Y-direction intervals in the Y-direction refined interval r_i whose first and last intervals are l and $\bar{l}$, respectively. If NAB is one, then $J_{(r_i)}^{mn}$ is approximated by

$$J_{(r_i)}^{mn} = \sum_{j=l}^{\bar{l}} \frac{1}{4} \delta_j (y_j + y_{j+1}) \left[H_m^{*'}(y_j) H_n'(y_j) + H_m^{*'}(y_{j-1}) H_n'(y_{j-1}) \right] \\ + \frac{1}{8} \delta_j^2 \left[H_m^{*'}(y_j) H_n'(y_j) - H_m^{*'}(y_{j-1}) H_n'(y_{j-1}) \right].$$

The partial integrals are temporarily stored in array RESULT and are written out on the data set whose reference number is LPART when all of the partial integrals of this type for the K th synthesis region with all of its Y-direction refined intervals have been calculated. The arrays HP and HADJP contain the derivatives of the functions H and H^* , respectively, and hence the functions H' and $H^{*'} are piecewise constant.$

For the calculation of the integrals I, the assumption is made that both H and H^* are linear between mesh-cell centers. Hence the partial integral $I_{(r_i)}^{mn}$ is approximated by $I_{(r_i)}^{mn}$, which is defined below with p equal to $1 - \text{NAB}$:

$$I_{(r_i)}^{mn} = \sum_{j=l}^{\bar{l}} \int_{y_{j-1}}^{y_j} \left[H_m^{*'}(y) \left(y - y_j - \frac{\delta_j}{2} \right) + H_m^*(y_j) \right] \left[H_n'(y) \left(y - y_j - \frac{\delta_j}{2} \right) + H_n^*(y_j) \right] y^p dy.$$

Here $H_m^{*'}(y)$ and $H_n^*(y)$ can each assume only two values in each interval, the numbers y are mesh-cell boundaries, and the j intervals all lie in the i th Y-direction refined region. Since by assumption the trial functions are linear between mesh-cell centers, the above approximation for $I_{(r_i)}^{mn}$ is replaced

$$\begin{aligned}
\hat{I}_{(r_1)}^{mn} = & \int_{y_{L-1}}^{\bar{y}_L} \left[H_m^*(y_L) \left(y - y_L - \frac{\delta_L}{2} \right) + H_m^*(y_L) \right] \left[H_n^*(y_L) \left(y - y_L - \frac{\delta_L}{2} \right) \right. \\
& \left. + H_n^*(y_L) \right] y^p dy + \int_{\bar{y}_L}^{\bar{y}_L} \left[H_m^*(y_L) \left(y - y_L - \frac{\delta_L}{2} \right) \right. \\
& \left. + H_m^*(y_L) \right] \left[H_n^*(y_L) \left(y - y_L - \frac{\delta_L}{2} \right) + H_n^*(y_L) \right] y^p dy \\
& + \sum_{j=L}^{\bar{L}-1} \int_{\bar{y}_j}^{\bar{y}_{j+1}} \left[H_m^*(y_j) \left(y - y_j - \frac{\delta_j}{2} \right) + H_m^*(y_j) \right] \left[H_n^*(y_j) \left(y - y_j - \frac{\delta_j}{2} \right) \right. \\
& \left. + H_n^*(y_j) \right] y^p dy.
\end{aligned}$$

Note that $\bar{y}_q$ are mesh-cell centers while y_p are mesh-cell boundaries.

Each term of every integrand is first expressed in the form $f = ay + b$. These polynomials are then multiplied and integrated with the internal function FRIEMN used to calculate the value of each integral. FRIEMN calculates $F(Y) \cdot F(X) = XMY \{ XPY^2 - (XPY^2 - 2^p XY)A + XPY^2 B + C \} - p^2 B^2 XY$. After all the partial integrals for all Y-direction refined intervals in synthesis region K have been calculated, they are written out on the data set whose reference number is LPARE.

d. Subroutines Called by This Subroutine. None.

e. Subroutine Calling This Subroutine. PROCES.

46. Subroutine RKIN(DEC ON, DICHL, DCGHL, NFAM, GMAX, M, K, *)

a. Arguments. The first three arguments are located in common block BLKSTR; the next three are defined in common block SINGLE, with M listed under MTRCHL. K is the data set reference number for A.KIN2D. The asterisk indicated error return to the calling subroutine.

b. Im stant cal riabl. None.

c. Functions and T's s Performed b This out c. This subroutine reads the ARC System data set A. 2D. R is not called when using the synthesis module, since it has no kinetics option.

d. Subroutine Called b This Subroutine. PAGED.

e. Subroutine Calling This Subroutine. RCOMP.

47. Subroutine RMESH(REGMSH,CMPMSH,MSHREG,MSHCMP, CMPREG,CRDUM,X,Y,DX,DY,BSQ,REGHHT,EXTHHT,REGNAM, LAREA,LZONE,NFIN,NIL,RMAX,IMAX,IMAX,NTAPE,*)

a. Arguments. The first 14 arrays are located in common block BLKSTR; arguments 19-21 are defined in common block SINGLE. The remaining arguments are defined below.

<u>Name</u>	<u>Type</u>	<u>Definition</u>
LAREA	I*4	Length of area record (record 06 of GEOM).
LZONE	I*4	Length of zone record (record 07 of GEOM).
NFIN	I*4	Number of finite geometry type.
NIL	I*4	Number of directions of finite geometry.
NTAPE	I*4	Data-set reference number for GEOM.
*		Error return to calling subroutine.

b. Important Local Variables

<u>Name</u>	<u>Type</u>	<u>Definition</u>
NR	I*4	Indicates the record number where a read error occurred.

c. Functions and Tasks Performed by This Subroutine. This subroutine reads record types 2-9 of data set GEOM and modifies the data for use by the synthesis module.

It first reads mesh-line locations from record type 2 into arrays X and Y and then sets up XL, XR, YT, and YE and the mesh-interval lengths DX and DY. It then reads region-to-mesh correspondence (record type 3), composition-to-mesh correspondence (record type 4), and composition-to-region correspondence (record type 5) into the temporary I*4 arrays MSHREG, MSHCMP, and CRDUM and transfers them to the I*2 arrays REGMSH, CMPMSH, and CMPREG for permanent storage. Record types 6 and 7 (area and zone definitions) are skipped if present.

Finite geometry data, including buckling, actual half-height and extrapolated half-height, are then read into the arrays BSQ, REGHHT, and EXTHHT from record type 8 if it is present. If buckling data for a given region R are not present, BSQ(R) is set to zero, and for any region and direction in which BSQ(R) is zero, both the actual and the extrapolated half-heights are set to 0.5.

Finally, the region names are read from record type 9 into array

d. Subroutine Called by This Subroutine. ERRMSG.

e. Subroutine Calling This Subroutine. RGEOM.

48. Subroutine RRCALC(SYNMSH, REGMSH, REFREG, IMAX, JMAX, RRMAX, LEN, KMAX, PHYREG, REF, RRFJ, RRJLOC, NUMRRJ, NUMMAX, MANY)

a. Arguments. Arrays 1-3 and 9-12 are defined in common block BLKSTR, with array REFREG listed as RR and array RRF listed as RRRFRST. The constants numbered 4-6 and 8 are listed in common block SINGLE. The remaining arguments are defined below.

<u>Name</u>	<u>Type</u>	<u>Definition</u>
LEN	I*4	The number of contiguous I*2 words used in array RRFJ starting with RRFJ(1) (used to redefine the storage for RRFJ).
NUMMAX	I*4	The maximum number of Y-direction refined intervals per synthesis region taken over all synthesis regions (used to define storage for array RESULT).
MANY	I*4	The maximum number of refined regions per synthesis region taken over all synthesis regions (used to define storage for arrays NUSIGF and SCTCOF).

b. Important Local Variables

<u>Name</u>	<u>Type</u>	<u>Definition</u>
IRRF	I*4	Pointer for array RRF to indicate where the first interval number of the next refined region can be stored.
IRR	I*4	First interval of a synthesis region.
JRR	I*4	Last interval of a synthesis region.
IRREND	I*4	Last refined region of a synthesis region K.
IPLACE	I*4	Position in RRFJ where the first interval of the next Y-direction interval is stored.

c. Actions and Tasks Performed by This Subroutine. The X-direction interval-to-region correspondence and the Y-direction refined intervals per refined region are calculated from left to right, with refined region 1, interval 1 as in a different region.

interval i if their respective synthesis regions or their respective Y-direction cuts differ. A Y-direction cut for interval i is the set of points j , $1 \leq j \leq J$, and the reactor region assignment $\{R_j^i\}_{j=1}^J$ for these cuts. Cuts are identical when $R_j^i = R_j^p$, $1 \leq j \leq J$ and $i \neq p$. Each synthesis region will contain a number of refined regions, each of which by definition contains identical cuts. Let $\{R_j^k\}_{j=1}^J$, $k = 1, \dots, N$, be the reactor-region assignments for the N refined regions in synthesis region k . Now if $\{R_j^k\}$ is the set of points j with the property that $R_{j-1}^k \neq R_j^k$ for each k , then $\bigcup \{R_j^k\}$ plus the point $j = 1$ is the set of first Y-direction intervals for each Y-direction refined interval in synthesis region k .

The integrations performed in subroutine PROCES are performed over these refined intervals for each synthesis region.

d. Subroutines Called by This Subroutine. None.

e. Subroutine Calling This Subroutine. RSDEF.

49. Subroutine RSDEF(*)

a. Arguments. The asterisk represents an error return to the calling subroutine.

b. Important Local Variables

<u>Name</u>	<u>Type</u>	<u>Definition</u>
MAXNUM	I*4	put value used by POINTR routines to allocate storage, MAXNUM $\geq$ NGKMX.
LLEN	I*4	Value returned by RRALC as the amount of storage required for array RRFJ, LLEN $\leq$ AX*JMAX.
NUMMAX	I*4	largest number of refined intervals in a synthesis region.
MANY	I*4	largest number of refined regions in any synthesis region.
NTRL	I*4	Value returned by RRALC as the amount of storage required for array NTRIAL, NTRL $\leq$ *KMAX*MAXNUM.
ICORE	I*4	passed to LIS to indicate whether, when rating the trial function libraries, all the trial functions can be included. ICORE = 1 -- Functions core-contained. = 0 -- Functions can be core-contained.

<u>Name</u>	<u>Type</u>	<u>Definition</u>
JFLAG	I*4	Error checking flag, set initially to zero. IFLAG = 0,2--No problem. IFLAG = 1--The consistency keys on the trial-function libraries do not match.

c. Functions and Tasks Performed by This Subroutine. This subroutine is a driver routine. RSDEF allocates storage, reads more of the module-dependent data, and calls other routines. The called routines define the synthesis regions and trial functions per region from the A.SYN2D data set, calculate the refined regions and refined intervals, generate the module-required trial-function libraries, and finally calculate the partial integrals over each refined interval. The original storage allocation for several of the arrays is redefined after the actual space required has been determined. Finally, arrays NN and NNP are equivalenced, since the present version of the code uses routines where the array NNP was defined.

d. Subroutines Called by This Subroutine PAGHED, ERRMSG, SYNDEF, SNIFF (ARC System subroutine), LIB, PROCES, DSRNCK, CLOSE.

e. Subroutine Calling This Subroutine. SYNIN.

50. Subroutine RVEL(VEL,GMAX,*)

a. Arguments. Array VEL is listed in common block BLKSTR, GMAX is defined in common block SINGLE, and the asterisk is an error return to the calling subroutine.

b. Important Local Variables

<u>Name</u>	<u>Type</u>	<u>Definition</u>
NTAPE	I*4	Data set reference number for XS.ISO.
NGROUP	I*4	Number of energy groups defined on XS.ISO.
NISO	I*4	Number of isotopes defined on XS.ISO.
ISO	R*8	Character variable used to read isotope names from XS.ISO.
LOC	I*4	Character variable used to read number of records in second file to be skipped in order to read isotope data for given isotope I.
NGFI	I*4	NUMBER + 1, for use in reading record type 3 of XS ISO.
IC	I*4	Fission-spectrum flag for isotope set.

<u>Name</u>	<u>Type</u>	<u>Definition</u>
E	R*8	Dummy variable used to read energy boundaries of groups.
U	R*8	Dummy variable used to read lethargy boundaries of groups.

c. Functions and Tasks Performed by This Subroutine. This subroutine reads neutron speeds for groups from record type 3 of data set XS ISO if the problem involves an α -search, a search for a prescribed α , or a nonzero α . If none of these conditions is met, the speeds are set to 1 in all groups. If the speeds are read from XS ISO and if the output flag KOUT is greater than zero, the speeds and the data-set reference number are printed.

d. Subroutines Called by This Subroutine. SNIFF (ARC System subroutine), PAGED, ERRMSG.

e. Subroutine Calling This Subroutine. RCOMP.

51. Subroutine RXSC01 (CMPNAM, N, *)

a. Arguments. Array CMPNAM is listed in common block BLKSTR. N is the data-set reference number for XS.C MIN, and the asterisk represents an error return to the calling subroutine.

b. Important Local Variables. None.

c. Functions and Tasks Performed by This Subroutine. This subroutine reads record type 1 of XS.C MIN to get the composition names.

d. Subroutine Called by This Subroutine. ERRMSG.

e. Subroutine Calling This Subroutine. RCOMP.

52. Subroutine SINCAL (*, SYNMSH, NN, PHI, FLX, NUSIGE, REFREG, WINT, JUNK, IMAX, KMAX, GMAX, NGKMX, NNP, PHI2)

a. Arguments. The first eight arguments following the asterisk and the last two arguments are defined in common block BLKSTR, with REFREG and NNP listed as R and NBP, respectively. The remaining arguments are defined in common block SINGLE. The asterisk indicates an error return to the calling subroutine.

b. Important Local Variables.

<u>Name</u>	<u>Type</u>	<u>Definition</u>
II	I*4	Pointer for array UINT in common block BLKSTR.

Name	Type	Definition
I2	I*4	Pointer for array HINT in common block BLKSTR.
I3	I*4	Pointer for array AREA in common block BLKSTR.
LAMDA	R*8	k-effective iterate.
RDX	R*8	1/k ⁽ⁿ⁻¹⁾ -effective.
ZLAMUP	R*8	$\bar{\lambda} = \max_{g,i,n} \left[\frac{\psi_{g,i,n}^{(L)}}{\psi_{g,i,n}^{(L-1)}} \right]$. If $\psi_{g,i,n}^{(L)} \frac{SUM(2)}{GIN} \leq$ EPSLAM, the ratio is not computed.
ZLAMDN	R*8	$\min_{g,i,n} \left[\frac{\psi_{g,i,n}^{(L)}}{\psi_{g,i,n}^{(L-1)}} \right]$. See comment above.
GLOW	I*4	Lowest energy-group scattering into group G.
GUP	I*4	Highest energy-group scattering into group G. (Since there is no upscattering, GUP = G.)
SUM(1)	R*8	$\sum_{g,i,n} \psi_{g,i,n}^{(L)} - \psi_{g,i,n}^{(L-1)} $
SUM(2)	R*8	$\sum_{g,i,n} \psi_{g,i,n}^{(L)} $
SUM(3)	R*8	$\langle \psi^{(L)}, \psi^{(L)} \rangle$ i.e., inner product of $\psi^{(L)}$ with itself.
SUM(4)	R*8	$\langle \psi^{(L)}, \psi^{(L-1)} \rangle$
RESULT(1)	R*8	k-effective for last iteration, k ⁿ⁻¹ .
RESULT(2)	R*8	k ⁿ - k ⁿ⁻¹ .
RESULT(3)	R*8	$\bar{\lambda}$.
RESULT(4)	R*8	λ .
RESULT(5)	R*8	$\bar{\lambda} - \lambda$.
RESULT(6)	R*8	SUM(1).
RESULT(7)	R*8	SUM(2).
RESULT(8)	R*8	SUM(1)/[SUM(2)*GIN]

Note the array RESUL holds this data for printing out. However, RESULT(7) is modified for computing $\bar{\lambda}$ and λ .

subroutine perfo ns no Tasks P r med b time. This
eigenvalue eigenv iterations require the dominant
tion H.B. #1 details desc ption of the mathema 61-71 in Sec-
valued

After a call to SNIFF to check on the disposition of the mixing-functions data set, FR TG is read if old and used as the initial approximation for this problem. If FR TG is not old, the first eigenvalue and each component of the eigenvector are set to one. Each iteration consists of solving the equation

$$P_g \psi_g = f_g, \quad g = 1, \dots, G,$$

for ψ_g . For each g the generation of f_g proceeds in the following manner. The fission matrices $F_{r(i)}^{g'g}$ are read for all g' , where $1 \leq g' \leq G$ and $r(i)$ is a refined region. Then the vectors q_i^g are defined as

$$q_i^g = \sum_{g'=1}^G \frac{w_i}{\lambda^{(n-1)}} F_{r(i)}^{g'g} \psi_{g'}^{(n-1)}, \quad 1 \leq i \leq I,$$

where $\psi_{g'}^{(n-1)}$ is a vector of length N_1 and $w_i = (\rho_i^\alpha - \rho_{i-1}^\alpha)/2$ with ρ_i as the right mesh-cell boundary and α is NALPHA from common block SINGLE. Note that the refined regions change as i increases, necessitating the reading of more fission matrices. Next the scattering matrices $S_{r(i)}^{g'g}$ are read for $g_L \leq g' < g$ and the vectors

$$p_i^g = \sum_{g'=g_L}^{g-1} w_i S_{r(i)}^{g'g} \psi_{g'}^{(n-1)}$$

are calculated. Finally, the vector $f_g = (f_g^1, f_g^2, \dots, f_g^I)$, with

$$f_g^i = p_i^g + q_i^g$$

is formed. The actual calculation of the vector p_i^g is performed by the routines SWEEP1 and SWEEP2. Both the fission and scattering matrices are stored in array NUSGF, while vector f_g is stored in array FLX and ψ is stored in array PHI. The LAMDA of the code is actually the desired k -effective. The matrices U_i^{-1} and V_i are read from the data set whose reference number is FLIB and stored in the same location in array BLK; the matrices H_i are read from the data set whose reference number is NLIB. The iterations are terminated when one of the following conditions is encountered:

- (1) An error the code checks for has been encountered.
- (2) Less than 30 sec computer time remains for the completion of this problem.
- (3) The required number of iterations has been completed.
- (4) The following convergence criteria have been satisfied:

$$|k^n - k^{n-1}| \leq \text{EPSKEF},$$

$$|\lambda_{up} - \lambda_{dn}| \leq \text{EPSLAM},$$

and

$$\frac{\sum_{g,i,n} |\psi_{g,i,n}^{(L)} - \psi_{g,i,n}^{(L-1)}|}{\text{GIN} \cdot \sum_{g,i,n} |\psi_{g,i,n}^{(L)}|} \leq \text{EPOFLX},$$

where G is the number of energy groups, I is the number of mesh points in the X direction, and N is the maximum number of trial functions used in any synthesis region for any group. The numbers EPSKEF, EPSLAM, and EPOFLX are user-supplied.

After the iterations have ceased, the data set FR.TG is written.

d. Subroutines Called by This Subroutine. MADD, SWEEP1, SWEEP2, PAGHED, GMPRD, TLEFT (IBM function), ERRMSG, NUMMLT, SNIFF (ARC System subroutine).

e. Subroutine Calling This Subroutine. SYNCAL.

53. Subroutine SINOUT(TG,FLX,HG,SYNMSH,NN,IMAX,JMAX,GMAX,KMAX,NGKMX,NALPHA,NBETA,NLIB)

a. Arguments. The first five arrays are defined in common block BLKSTR; the remaining arguments are defined in common block SINGLE.

b. Important Local Variables

<u>Name</u>	<u>Type</u>	<u>Definition</u>
AA(13)	R*8	Alpha numeric data.
BB(9)	R*8	Alpha numeric data.
CC(30)	R*8	Alpha numeric data.
ROWT	R*8	Row title used by TWODPR.
COLT	R*8	Column title used by TWODPR.
K	I*4	Synthesis region indicator.
G	I*4	Present energy group number.
NGK	I*4	Number of trial functions for energy group G and synthesis region K.

d. Functions and Tasks Performed by This Subroutine. This subroutine sets up information for the printout routine TWODPR, calculates the reconstituted flux

$$\phi_{gk}(x,y) = \sum_{n=1}^{N_{gk}} H_{gk}^n(y) T_g^n(x).$$

for all energy groups g and synthesis regions k , and writes it out on the data set whose reference number is NLIB. It also prints out the mixing functions T_g and, if the print flag KOUT is greater than zero, it prints out the real trial functions H_{gk} .

d. Subroutine Called by This Subroutine. TWODPR.

e. Subroutine Calling This Subroutine. SYNOUT.

54. Subroutine STORBC(SAVE,BNDC,NBC)

a. Arguments.

<u>Name</u>	<u>Type</u>	<u>Definition</u>
SAVE(11)	R*4	Address of MSHTYP from subroutine RBNDC (location of common block BCBLK).
BNDC (11,NBCDEF)	R*4	Boundary-condition data from data set BC. (Refer to common block BLKSTR).
NBC	I*4	Number of boundary-condition record just read in RBNDC.

b. Important Local Variables. None.

c. Functions and Tasks Performed by This Subroutine. For each boundary condition NBC, $NBC = 1, \dots, NBCDEF$, defined in data set BC, this subroutine stores the 11 boundary-condition definition terms in the locations (1,NBC), ..., (11,NBC) of the array BNDC. The boundary-condition terms are obtained from the common block BCBLK through referencing its first element, MSHTYP. The first one and last four elements of each 11 in BNDC are R*4. The rest are I*4.

d. Subroutines Called by This Subroutine. None.

e. Subroutine Calling This Subroutine. RBNDC.

55. Subroutine SWEEP1(UINT,AREA,NN,SYNMSH,HINT,NGKMX,IMAX,GMAX,KMAX,FLX)

Entry points

Entry: SWEP1(G)

a. Arguments. The first five arguments and the last argument are defined in common block BLKSTR; the remaining arguments are defined in common block SINGLE. The argument G in entry point SWEP1 is the present energy-group number.

b. Important Local Variables. None.

c. Functions and Tasks Performed by This Subroutine. We have $P_g \hat{g} = F$, where $P_g = L_g \hat{U}_g$, L_g being lower triangular and $\hat{U}_g$ being upper triangular. (Note that P is a tridiagonal matrix whose elements are matrices.) This routine begins to invert P , i.e., it calculates $W = L^{-1}F$. (Note that $FLX = F$, with $F = (f_1 \dots f_{IMAX})$ and $W = (w_1 \dots w_{IMAX})$.) The actual inversion of L is performed in subroutine MTGEN2. The calculation of w_i is performed as follows for each group:

$$w_i = U_i^{-1} f_i \quad \text{for } i = 1,$$

$$w_i = U_i^{-1} (f_i + H_i w_{i-1}) \quad \text{for } i = 2, 3, \dots, IMAX.$$

For a more detailed description, refer to Section II.B.

The array FLX that the subroutine returns is the new W , which is then operated upon in EP2. Thus, the array FLX contains first F and then W . The calling sequence just initializes the subroutine.

d. Subroutines Called by This Subroutine. GMPRD, MOVE, MADD.

e. Subroutine Called by This Subroutine. SINCAL.

56. Subroutine SWEEP2(EA,NN,SYNMSH,VINT,NGKMX,IMAX,GMAX,KMAX,FLX)

Entry points

Entry: SWEP2(G)

a. Arguments. The first four arguments and the last are defined in common block BLKSTR, with VINT listed as GINT. The remaining arguments are defined in common block SINGLE. The entry-point argument G is the present energy-group number.

b. Important Local Variables. None.

c. Functions and Tasks Performed by This Subroutine. We have $L_g U_g \Phi_g = F_g$, L_g being lower triangular and U_g being upper triangular. (Note that $L_g U_g$ is a tridiagonal matrix whose elements are matrices.) In SWEEP1 we inverted L_g and obtained $U_g \Phi_g = L_g^{-1} F_g = W_g$; now we will obtain $\Phi_g = U_g^{-1} W_g$. The actual inversion of U_g is done in subroutine MTGEN2. The calculation of Φ_g proceeds as follows for each group, with $W_g = (w_1, \dots, w_{IMAX})$.

$$\Phi_{g,IMAX} = w_{g,IMAX} \quad \text{for } i = IMAX;$$

$$\Phi_{g,i} = w_{g,i} + w_{g,i+1} \Phi_{g,i+1} \quad \text{for } i = IMAX - 1, \dots, 2, 1.$$

Refer to Section II.B for a more detailed description. The array FLX that the subroutine returns is actually Φ_g , although initially FLX held W_g . When we have finished, Φ_g represents one iteration toward an approximation of the mixing functions. The calling sequence just initializes the subroutine.

d. Subroutines Called by This Subroutine. GMPRD, MADD.

e. Subroutine Calling This Subroutine. SINCAL.

57. Program SYN2D (Main program)

a. Arguments. None.

b. Important Local Variables. None.

c. Functions and Tasks Performed by This Program. This program is the main driver for the module. It calls all the subroutines either directly or indirectly. It also prints out a message telling how long execution of the module took.

d. Subroutines C d b This Program. CLOSE, SYNIN, DZDCAL, SYNOUT, FREE.

e. Program C lli This Program, STP012, the two-dimensional synthesis path.

58. Subroutine SYNCAL *)

a. Arguments. T asterisk indicates an error return to the calling subroutine.

b. Important Local Variables. None.

c. Functions and Tasks Performed by This Subroutine. This subroutine is a driver for the power iterations. It sets up storage for the arrays that will be required by the iteration subroutine, calculates

$$\omega_i = \begin{cases} \delta_i r_i & \text{if NALPHA} = 1, \text{ RZ geometry} \\ \delta_i & \text{if NALPHA} = 0, \text{ XY or ZR geometry} \end{cases}$$

and prints out a message telling how long it took to execute the subroutine.

d. Subroutines Called by This Subroutine. EERRMSG, SINCAL, TLEFT (IBM function).

e. Subroutine Calling This Subroutine. D2DCAL.

59. Subroutine SYNDEF(GMAX, KMAX, IMAX, SYNMSH, LIBFLX, NN, X, NZERO, NTRIAL, XSYNPT, MAXNUM, NTRL, *).

a. Arguments. The first three arguments are defined in common block SINGLE; the next seven arrays are defined in common block BLKSTR. The integer MAXNUM is defined in the data-set specifications for A.SYN2D card type 04 columns 19-24. NTRL is returned as the number of I*2 locations used in array NTRIAL. The asterisk represents an error return to the calling subroutine.

b. Important Local Variables

<u>Name</u>	<u>Type</u>	<u>Definition</u>
GINT	I*4	First group for which the trial-function input information applies.
GFIN	I*4	Last group for which the trial-function input information applies. (It applies to all G for which INT ≤ G ≤ GFIN.)
NSTATS	I*4	Flag to indicate whether card type 06C is present should be read (Card read if NSTATS ≠ 0); also used to indicate position in NTRIAL for given group G and synthesis region K where data from the type-06C card are stored.
NGK	I*4	Temporarily holds number of real trial functions in synthesis region K for group G.

c. Function and Tasks Performed by This Subroutine. This subroutine reads synthesis boundary points (XSY and terminates the interval-to-synthesis region correspondence (SYNMSH). It also reads in the function numbers, from data set A.SYN2D, for the trial functions to be used for each group in a given synthesis region. This routine also reads in the function flags which indicate whether the trial functions in a given

synthesis region and energy group satisfy the boundary condition $\phi = 0$ at the reactor top and/or bottom. These data, if present, are stored in array NTRIAL and indexed through array NZERO. This subroutine also prints out the synthesis boundaries that it will use in its calculations.

d. Subroutine Called by This Subroutine. ERRMSG.

e. Subroutine Calling This Subroutine. RSDEF.

60. Subroutine SYNGEN(*)

a. Arguments. The asterisk indicates an error return to the calling subroutine.

b. Important Local Variables

<u>Name</u>	<u>Type</u>	<u>Definition</u>
KBAR	I*4	KMAX - 1. used for dimensioning.
NOWMAX	I*4	Equals NGKMX (see INT.103 in common block SINGLE).
IM1	I*4	IMAX - 1. used for allocating storage.
IGM	I*4	GMAX - 1. used by subroutine COFGEN.

c. Functions and Tasks Performed by This Subroutine. This subroutine allocates the storage space in array BLK which will be needed later to store the finite-difference matrices. All synthesis-related matrix calculations are controlled by this subroutine and those called by it. The subroutine prints out the time required for execution of this section, and if a detectable error is encountered, it prints out an error message. It initializes several subroutines which are later called at their entry points.

d. Subroutines Called by This Subroutine. TLEFT (IBM function), COFGEN, CLOSE, ERRMSG, CHECK, MTGEN1, MTGEN2, SNIFF (ARC System subroutine).

e. Lin T broutine. D2DCAL.

61. r ne Y *)

a. Arguments. The asterisk indicates an error return to the calling subroutine.

b. Im nt al Var les. None.

c. Functions and Tasks Performed by This Subroutine. SYNIN is a driver subroutine. It calls subroutines that read in module-dependent data, calculate required information from the user's input, including partial integrals, refined regions, Y-direction refined intervals, etc., and store these data until needed by other sections of the code. It also prints out a message giving the time spent in execution of the subroutine.

d. Subroutines Called by This Subroutine. RCDEP, RGEOM, RCOMP, RBND, RSDEF, TLEFT (IBM function).

e. Subroutine Calling This Subroutine. SYN2D.

62. Subroutine SYNOUT(*)

a. Arguments. The asterisk indicates an error return to the calling subroutine.

b. Important Local Variables. None.

c. Functions and Tasks Performed by This Subroutine. This subroutine is a driver for the printout subroutine. It wipes out arrays from BLK and creates storage for the reconstituted flux and trial functions. Then the output subroutines are called. Finally, it prints a message telling the time it took to execute SYNOUT. Note that subroutine D2DOUT is a two-dimensional diffusion subroutine, as are the subroutines called by D2DOUT.

d. Subroutines Called by This Subroutine. TLEFT (IBM function), SINOUT, D2DOUT.

e. Subroutine Calling This Subroutine. SYN2D.

63. Subroutine TWODPR(ARRAY, ICT, JCT, TITLE, ROWT, COLT, INVRT, IPONE, JPONE, RNUM, CNUM)

a. Arguments

<u>Name</u>	<u>Type</u>	<u>Definition</u>
ARRAY (ICT, JCT)	R*8	two-dimensional array to be printed.
ICT	I*4	number of rows in array.
JCT	I*4	number of columns in array.
TITLE(9)	R*8	title of array (9A8).
ROWT	R*8	row title (A8).
COLT	R*8	column title (A8).

N.

1.

<u>Name</u>	<u>Type</u>	<u>Definition</u>
INVRT	I*4	Array transposition flag. 0--Print array as given. 1--Transpose rows and columns in printing.
IPONE	I*4	Row numbering flag. 0--Number rows with integers 1, 2, ..., ICT for INVRT = 0, or 1, 2, ..., JCT for INVRT = 1. 1--Number rows with members of floating-point array RNUM. 2--Label rows with members of alphanumeric array RNUM.
JPONE	I*4	Column numbering flag. 0--Number columns with integers 1, 2, ..., JCT for INVRT = 0, or 1, 2, ..., ICT for INVRT = 1. 1--Number columns with members of floating-point array CNUM. 2--Number columns with integers JCT for JCT = 1, ..., 1 for INVRT = 0, or ICT for ICT = 1, ..., 1 for INVRT = 1.
RNUM (ICT or JCT)	R*8	Numbers or labels for rows if IPONE = 1 or IPONE = 2.
CNUM (JCT or ICT)	R*8	Numbers for columns if JPONE = 1.

b. Important Local Variables

<u>Name</u>	<u>Type</u>	<u>Definition</u>
II	I*4	Number of first row to be printed on page for INVRT = 0.
IJ	I*4	Number of first row to be printed on page for INVRT = 1.
IMAX	I*4	Number of last row to be printed on page for INVRT = 0.
JMAX	I*4	Number of last row to be printed on page for INVRT = 1.
MIN	I*4	Number of first column to be printed on page.
MAX	I*4	Number of last column to be printed on page.

<u>Name</u>	<u>Type</u>	<u>Definition</u>
IFLAG	I*4	New page flag. 0--Start new page. 1--Stay on same page ($NROW + IDIF < 57$).
IEND	I*4	Number of last column (JCT for $INVRT = 0$, ICT for $INVRT = 1$).
NROW	I*4	Approximate number of rows printed on page (sum of IDIF's).
JCI	I*4	Increasing index on columns, $JCI = 1, \dots$ $MAX - MIN + 1$.
JFLIP(7)	I*4	Flipped column integer indices for $JPONE = 2$: $IEND - MIN + 1, IEND - (MIN + 1) + 1, \dots, IEND - MAX + 1$.
IDIF	I*4	Approximate number of rows printed in pass: $IDIF = (IMAX - IJ) + 5$ for $INVRT = 0$, $IDIF = (JMAX - IJ) + 5$ for $INVRT = 1$.
ID	I*4	Integer row number, for $IPONE = 0$.
FID	R*8	Floating-point number $RNUM(1)$ for $IPONE = 1$, or alphanumeric label $RNUM(1)$ for $IPONE = 2$.

ons and Tasks Performed This subroutine prints a given two-dimensional array $Y(I, JCT)$ in a format selected using the various options offered by subroutine. The array is printed with a maximum of seven columns and five rows to a page. All rows are printed for a given group of seven or less columns before the next set of columns is begun.

The major option offered is that of transposing array, by setting $INVRT$ to 1, so that rows are printed as columns and columns as rows. This does not affect the array contents, but only the order in which they are printed. It also does not affect column and row headings and labels; these are used as input and are not affected by the $INVRT$ flag.

Other options control the manner in which column and row titles are indexed. A general column title is printed once each column and a general row title before every row; these general titles can be followed by various types of individual labels.

For rows, the options are as follows:

$IPONE = 0$: The rows are numbered with the integers $1, 2, \dots, IEND$.
 $INVRT = 0$; for $INVRT = 1$, the range is $1, 2, \dots, JCT$.

IPONE = 1: The rows are numbered with the members of the floating-point array RNUM(ICT) for INVRT = 0, or RNUM(JCT) for INVRT = 1, in F10.3 format.

IPONE = 2: The rows are labeled with the members of the alphanumeric array RNUM(ICT) for INVRT = 0, or RNUM(JCT) for INVRT = 1, in A8 format.

For columns, the options are as follows.

JPONE = 0: The columns are numbered with the integers 1, 2, ..., JCT for INVRT = 0, or 1, 2, ..., ICT for INVRT = 1.

JPONE = 1: The columns are numbered with the members of the floating-point array CNUM(JCT) for INVRT = 0, or CNUM(ICT) for INVRT = 1, in F10.3 format.

JPONE = 2: The columns are numbered with the integers JCT, JCT - 1, ..., 1 for INVRT = 0, or ICT, ICT - 1, ..., 1 for INVRT = 1.

If IPONE is zero, any array or dummy variable can be used in the calling sequence in place of RNUM, since RNUM will not be used; the same holds true for CNUM when JPONE is either zero or two.

As many complete sets of seven columns, each for all rows, as can be fit on one page will be printed to a page. Breaking up of sets of seven columns on successive pages will be done only if there are more than 52 rows. On each page, the general page heading and page number, set up in common block HEADER for subroutine PAGHED, are printed, followed by the input array title. Column and row headings are printed for each column and row. Array members are printed in IPE15.6 format.

d. Subroutine Called This Subroutine PAGHED.

e. Subroutines called This Subroutine SINOUT, ITOBAL, FLUXPR.

64 Subroutine VAL S(HG,HP,HADJG,HADJP,JMAX,LPART, RESULT,DY, G X)

Entry points

Entry: VALUE(G,HP,HADJG,HADJP,NGK)

a. Arguments. The first four arguments as well as the seventh and eighth are listed in common block BLKSTR; the three remaining constants are defined in common block SINGLE. The constant NGK is the number of trial functions being passed in the arrays HG and HADJG.

b. Important Local Variables None.

c. Functions and Tasks Performed by This Subroutine. This subroutine computes the values of the trial functions at the reactor top and bottom for all the trial functions in a given synthesis region and group. The computed values of the real and adjoint trial functions and their associated derivatives are then written out on the data set whose reference number is LPART. These numbers will be used later to calculate the boundary matrices. For the reactor top, the value H_T is computed as follows for each trial function:

$$H_T = 0.5\delta_J H_J' + H_J$$

where δ_J is the length of the last interval J . For the reactor bottom, the value H_B is computed for each trial function as follows:

$$H_B = -0.5\delta_I H_I + H_I$$

Repeated calls to this subroutine are made for each synthesis region and energy group. Note that the arrays passed in the entry calling sequence are subarrays, consisting of half of the original arrays.

d. Subroutines Called by This Subroutine None.

e. Subroutine Calling This Subroutine PROCES.

E. Data-set Usage

This section contains descriptions of all data sets used by this module. For each data set used, the following information is given:

1. The name of the data set, if it is an ARC System data set, or a description of its contents and function, if it is a scratch data set used only within the module.

2. The record structure of the data set, if it is a scratch data set.

3. Names of subprograms in which the data set is read and/or written, along with a list of record types that are read and/or written and the name of the variable containing the data-set reference number.

A complete description of the record structure and contents of each ARC System data set appears in ANL-7711.

1. A.SY

a. Name A.

Module de

Input

b. Record Structure Refer to A SYN2D Data-set Specifications Section II.E.

<u>Read in Subroutines</u>	<u>Card Types</u>	<u>Reference Variables</u>
RCDEP	Types 01-03	N.
RSDEF	Type 04	NINPUT
SYNDEF	Types 05,06A, 06B,06C	NINPUT
LIB	Type 07	NYSN2D

c. Written in Subroutines None.

2. Data Set BC

a. Name BC, Boundary Condition Specifications.

b. Record Structure ARC System data set.

<u>Read in Subroutines</u>	<u>Record Types</u>	<u>Reference Variables</u>
RBND C	All	NTAPE

c. Written in Subroutines None.

3. Data Set FA TRIAL

a. Name FA TRIAL, User-input Adjoint Synthesis Trial-function Library.

b. Description. The adjoint trial-function library for all groups, which is user-supplied. Each record after the first contains one adjoint trial function for each energy group.

c. Structure and Content

(1) Logical Record 1.

<u>Word Number</u>	<u>Variable Name</u>	<u>Type</u>	<u>Description</u>
1	LCMAX	I*	Number of records that follow.
2	JMAX	I*	Number of function values for each function.
3	GMAX	I*	Number of energy groups.

(2) Logical Record I $2 \leq I \leq \text{LCMAX} + 1$

<u>Record Format</u>	<u>Type</u>	<u>Description</u>
((HG(J,G),J=1,JMAX),G=1,GMAX))	R*8	Adjoint library trial-function number I-1 for all groups.

<u>Read in Subroutines</u>	<u>Record Types</u>	<u>Reference Variables</u>
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LIB	All required	LIBNO
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d. Written in Subroutines None. (Refer to Section II.H.)

4. Data Set FR.D2

a. Name. FR.D2, Two-dimensional Real Group Fluxes.

b. Record Structure. ARC System data set.

<u>Read in Subroutine</u>	<u>Record Types</u>	<u>Reference Variable</u>
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RFLUX	All	NTAPE
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<u>Written in Subroutine</u>	<u>Record Type</u>	<u>Reference Variable</u>
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IGPCAL	All	NX
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5. Data Set FR.PN

a. Name. FR.PN, Power-normalized Real Regional Group Fluxes.

b. Record Structure. ARC System data set.

Read in subroutines. None.

<u>Written in Subroutine</u>	<u>Record Types</u>	<u>Reference Variable</u>
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IFXNEM	All	NFRPN
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6. Data Set FR.TG

a. Name. FR.TG, Mixing Functions.

b. Description. One dimensional multigroup mixing functions and their associated k-effective.

c. Structure and Content(1) Logical Record 1

<u>Word Number</u>	<u>Variable Name</u>	<u>Type</u>	<u>Description</u>
1	KEFF	R*8	k-effective.
2	GMAX	I*4	Number of energy groups.
3	KMAX	I*4	Number of synthesis regions.
4	IMAX	I*4	Number of synthesis direction space points.

(2) Logical Record 2

<u>Record Format</u>	<u>Type</u>	<u>Description</u>
((NNP(G,K),G=1,GMAX), K=1,KMAX)	I*4	The number of real trial functions used in synthesis region K, energy group G.

(3) Logical Record 3

<u>Record Format</u>	<u>Type</u>	<u>Description</u>
((((TG(N,I,G),N=1,NGKMX), I=1,IMAX),G=1,GMAX)	R*8	The mixing function value for trial function N at space point I for energy group G. Note that NGKMX = max (NNP(G,K)). G,K

<u>Read in Subroutine</u>	<u>Record Types</u>	<u>Reference Variable</u>
SINCAL	All	LIB1

<u>Written in Subroutine</u>	<u>Record Types</u>	<u>Reference Variable</u>
SINCAL	All	LIB1

7. Data Set FR.TRIA

a. Name. FR.T IAL, User-input Real Synthesis Trial-function Library.

b. Description. The real trial-function library for all groups, which is user-supplied. Each record after the first contains one real trial function for each energy group.

c. Structure and Content(1) Logical Record 1

<u>Word Number</u>	<u>Variable Name</u>	<u>Type</u>	<u>Description</u>
1	LCMAX	I*4	The number of records that follow.
2	JMAX	I*4	Number of function values for each function.
3	GMAX	I*4	Number of energy groups.

(2) Logical Record I $2 \leq I \leq \text{LCMAX} + 1$

<u>Record Format</u>	<u>Type</u>	<u>Description</u>
((HG(J,G),J=1,JMAX),G=1,GMAX)	R*8	Real library trial function number I - 1 for all groups.

<u>Read in Subroutine</u>	<u>Record Types</u>	<u>Reference Variable</u>
LIB	All required	LIBNO

d. Written in Subroutines. None. (Refer to Section II.H.)8. Data Set GEOMa. Name. GEOM, Geometry Data.b. Record Structure. ARC System data set.

<u>Read in Subroutine</u>	<u>Record Types</u>	<u>Reference Variables</u>
RGEOM	1	NTAPE
RMESH	All of 2-9 present	NTAPE

c. Written in Subrou es. None.9. Data Set LIB.ADJTa. Name. LIB.ADJT. Code-refined Adjoint Trial-function Library.b. Description. This data set contains all the adjoint trial functions required by this problem and only those required by this problem. LIB.ADJT is generated by module YN2D from a more general data set containing many trial functions (F TRIAL). This data set is used to

generate the partial integrals $TIME2$ defined below, keys the four data sets LIB.ADJT, LIB.MIX, LIB.PART; and LIB.REAL to ensure that they are consistent with each other and with the problem. $TIME2$ must be the same on each of these data sets.

c Structure and Content

(1) Logical Record 1

<u>Word Number</u>	<u>Variable Name</u>	<u>Type</u>	<u>Description</u>
1	TIME2	R*4	Data-set consistency key.
2	GMAX	I*4	Number of energy groups.
3	JMAX	I*4	Number of points at which trial functions are defined.
4	KMAX	I*4	Number of synthesis regions.
5	NGKMX	I*4	Maximum number of trial functions in any synthesis region for any group.

(2) Logical Record 2

<u>Record Format</u>	<u>Type</u>	<u>Description</u>
((NN(G,K),G=1,GMAX), K=1,KMAX)	I*2	The number of adjoint trial functions used in synthesis region K, energy group G.

(3) Logical Record 1 $3 \leq I \leq GMAX * KMAX + 2$

<u>Record Format</u>	<u>Type</u>	<u>Description</u>
((HG(J,N),J=1,JMAX), N=1,NGK)	R*8	the set of adjoint trial functions used in synthesis region K, energy group G, where $G = (G-1)*KMAX + K + 2$. NGK is the number of adjoint trial functions in synthesis region K, energy group G.

<u>Read in Subroutines</u>	<u>Record Types</u>	<u>Reference Variables</u>
DSRNCK	1 and 2	LADJT
PROCES	1	LADJT
<u>Written in Subroutine</u>	<u>Record Types</u>	<u>Reference Variables</u>
LIB	All	N2 LIB LIBRIT

10. Data Set LIB.MIX

a. Name. LIB.MIX, Code-refined Real Trial-function Library.

b. Description. This data set contains all the real trial functions required by the problem and only those required by the problem. The data set LIB.MIX is generated by module SYN2D from a more general data set containing many trial functions (FR.TRIAL). This data set is used to generate the partial integrals. Refer to data set LIB.ADJT (Section 9 above).

c. Structure and Content

(1) Logical Record 1

<u>Word Number</u>	<u>Variable Name</u>	<u>Type</u>	<u>Description</u>
1	TIME2	R*4	Data set consistency key.

(2) Logical Record 2 $2 \leq i \leq \text{GMAX} * \text{KMAX} + 1$

<u>Record Format</u>	<u>Type</u>	<u>Description</u>
((HG(J,N),J=1,JMAX), N=1,NGK)	R*8	The set of real trial functions used in synthesis region K, energy group G, where $1 = (K-1)*\text{GMAX} + G + 1$. JMAX is the number of points at which the trial functions are defined, NGK is the number of real trial functions in synthesis region K, energy group G. KMAX is the number of synthesis regions, and GMAX is the number of energy groups.

<u>Read in Subroutines</u>	<u>Record Types</u>	<u>Reference Variables</u>
DSRNCK	I	LMIX
PROCES	All	LMIX

<u>Written in Subroutine</u>	<u>Record Types</u>	<u>Reference Variables</u>
LIB	All	N3

11. Data Set LIB.PART

a. Name. LIB.PART Partial Integrals.

b. Description. This data set contains all the partial integrals required by the problem, plus the calculated values of the real and adjoint trial functions at the reactor top and bottom and their derivatives.

i.e., $H_{gk}^n(0)$, $H_{gk}^n(h)$, $H_{gk}^{*n}(0)$, $H_{gk}^{*n}(h)$, $H_{gk}^n(0)$, $H_{gk}^n(h)$, $H_{gk}^{*n}(0)$ and $H_{gk}^{*n}(h)$.

The data set LIB.PART is calculated using the trial functions from data sets LIB.ADJT and LIB.MIX. Refer to data set LIB.ADJT (Section 9 above).

c. Structure and Content

(1) Logical Record 1

<u>Word Number</u>	<u>Variable Name</u>	<u>Type</u>	<u>Definition</u>
1	TIME2	R*4	Data-set consistency key.
2	GMAX	I*4	Number of energy groups.
3	KMAX	I*4	Number of synthesis regions.

(2) Logical Record 2

<u>Record Format</u>	<u>Type</u>	<u>Definition</u>
(NUMRRJ(K), K=1, KMAX)	I*2	The number of Y-direction refined intervals per synthesis region.
((NN(G,K), G=1, GMAX), K=1, KMAX)	I*2	The number of trial functions per synthesis region and energy group.

(3) Logical Record I $3 \leq I \leq GMAX(KMAX(GMAX+5)-3) + 2$

There are six types of logical records which record I can be.

<u>Record Type</u>	<u>Record Format</u>	<u>Type</u>	<u>Definition</u>
3	((R(M,N,L), L=1,NM), M=1,NA), N=1,NR)	R*8	Partial integrals of $\int H_{gk}^n H_{gk}^{*n} dy$, where NM is the number of Y-direction refined intervals for synthesis region k, NA is the number of adjoint trial functions in synthesis region k for energy group g, and NR is the number of real trial functions in synthesis region k for energy group g.

<u>Record Type</u>	<u>Record Format</u>	<u>Type</u>	<u>Definition</u>
4	(HG(M), M=1, NGK), (HP(M), M=1, NGK), (HADJG(M), M=1, NGK), (HADJP(M), M=1, NGK), (RG(M), M=1, NGK), (RP(M), M=1, NGK), (RADJG(M), M=1, NGK), (RADJP(M), M=1, NGK)	R*8	Calculated values of the real and adjoint trial functions and their derivatives at the reactor top and bottom for each group. The first four arrays are the real trial functions and derivatives followed by the adjoint trial functions and derivatives for the reactor top. The last four arrays have the same structure for the reactor bottom.
5	((R(M, N, L), L=1, NM), M=1, NR), N=1, NR)	R*8	Partial integrals of $\int H_{gk}^{*n} H_{gk}^n dy$, where NM is the number of Y-direction refined intervals for synthesis region k and NR is the number of real trial functions for energy group g synthesis region k.
6	((R(M, N, L), L=1, NM), M=1, NA), N=1, NR)	R*8	Partial integrals of $\int H_{g,k-1}^{*m} H_{gk}^n dy$, where NM is the number of Y-direction refined intervals in synthesis region k - 1, NA is the number of adjoint trial functions in synthesis region k - 1, energy group g, and NR is the number of real trial functions in synthesis region k, energy group g.
7	((R(M, N, L), L=1, NM), M=1, NA), N=1,)	R*8	Partial integrals of $\int H_{g,k-1}^{*m} H_{gk}^n dy$, where NM is the number of Y-direction refined intervals in synthesis region k, NA is the number of adjoint trial functions in synthesis region k - 1, energy group g, and NR is the number of real trial functions in synthesis region k, energy group g.

<u>Record Type</u>	<u>Record Format</u>	<u>Type</u>	<u>Definition</u>
8	((R(M,N,L),L=1,NM), M=1,NA),N=1,NR)	R*8	Partial integrals of $\int H_{gk}^{*m} H_{g,k-1}^n dy$, where NM is the number of Y-direction refined intervals in synthesis region k - 1, energy group g, NA is the number of adjoint trial functions in synthesis region k, and NR is the number of real trial functions in synthesis region k - 1.

These records are written out with the following structure and logic.

```

DO 10 LG=1,GMAX
DO 10 K=1,KMAX
DO 10 G=1,GMAX
WRITE RECORD TYPE 3
If LG/G GO TO 10
WRITE RECORD TYPES 4 and 5
If K > 1 WRITE RECORD TYPES 6, 7, and 8
10 CONTINUE

```

<u>Read in Subroutines</u>	<u>Record Types</u>	<u>Reference Variables</u>
COFGEN	1, 2, and 1, where 1 is all record type 3-8 except type 4.	LPART
BCONDS	All type records.	LPART
<u>Written in Subroutines</u>	<u>Record</u>	<u>Reference Variables</u>
PROCES	1 and 2.	LPART
RIEMAN	All record types 3-8, except type 4.	LPART
VALUES	Record type 4.	LPART

12. LIB.R

Library. Name LIB. AL. Code-refined Real Trial-function

b. Description This data set contains all the real trial functions required by the problem and only those required by the problem. LIB.REAL is generated by module SYN2D from a more general data set containing many trial functions (FR.TRIAL). The sole function of the data set is to supply the real trial functions in proper form to reconstitute the final two-dimensional flux. Refer to data set LIB.ADJT

c. Structure and Content

(1) Logical Record 1

<u>Word Number</u>	<u>Variable Name</u>	<u>Type</u>	<u>Description</u>
1	TIME2	R*4	Data-set consistency key.

(2) Logical Record 1 $2 \leq I \leq KMAX*GMAX + 1$

<u>Record Format</u>	<u>Type</u>	<u>Description</u>
((HG(J,N),J=1,JMAX),N=1,NGK)	R*8	The set of real trial functions used in synthesis region K, energy group G where $I = (G-1)*KMAX + K + 1$. JMAX is the number of points at which the trial functions are defined. NGK is the number of real trial functions in synthesis region K, energy group G. KMAX is the number of synthesis regions, and GMAX is the number of energy groups.

<u>Read in Subroutines</u>	<u>Record Types</u>	<u>Reference Variables</u>
DSRNCK	I	LREAL
SINOUT	All	LIB
<u>Written in Subroutine</u>		<u>Reference Variables</u>
LIB	All	LIB LIBRIT

13. Data Set SCR001

a. Name SCR001, scratch Data Set 1

b. This scratch data set is used by the module SYN2D to temporarily hold trial functions while creating data sets LIB.ADJT, LIB.MIX, and LIB.REAL. SCR001 is used only if the real trial function cannot be

core-held. Next, SCR001 is used to hold the matrices $\{H_{ij}\}_{i=1}^{JMI}$ for all energy groups. Finally, SCR001 temporarily stores the unnormalized two-dimensional fluxes before output editing.

c. Structure and Content

(1) Logical Record I. This contains the real trial functions for all synthesis regions for energy group one. This data set aids in creating LIB.REAL. The functions appear on this data set in the same order as obtained from the data set ER.TRIAL. If the same real trial function is used in two or more synthesis regions, it will appear that number of times on this data set, i.e., the same trial function will be written that many times consecutively. All records have the same format. There are $\bar{N}$ records,

$\bar{N} = \sum_{k=1}^K N_{g,k}$, where $N_{g,k}$ is the number of trial functions required for energy group g, synthesis region k.

<u>Record Format</u>	<u>Type</u>	<u>Definition</u>
(HG(J), J=1, JMAX)	R*8	Real trial function defined at JMAX Y-direction space points.

<u>Read in Subroutine</u>	<u>Records</u>	<u>Reference Variable</u>
LIB	All	IDSN

<u>Written in Subroutine</u>	<u>Records</u>	<u>Reference Variable</u>
LIB	All	IDSN

(2) Logical Record II. This contains the same trial functions as I above. This data set aids in creating LIB.MIX. In this case, the trial functions have been re-ordered by synthesis regions, i.e., the trial functions for the first region are first, followed by those for the second, etc.

<u>Record Format</u>	<u>Type</u>	<u>Definition</u>
(HG(J), J=1, JMAX)	R*8	The real trial functions defined at JMAX space points.

<u>Read in Subroutine</u>	<u>Records</u>	<u>Reference Variable</u>
LIB	All	IDSN

<u>Written in Subroutine</u>	<u>Records</u>	<u>Reference Variable</u>
LIB	All	IDSN

(3) Logical Record III. This contains the adjoint trial functions for all synthesis regions for energy group one. This data set aids in creating LIB. The functions appear on this data set in the same order as obtained from the data set FA.TRIAL. If the same adjoint trial function is used in two or more synthesis regions, it will appear that number of times on this data set, i.e., the same adjoint function will be written that many times consecutively. All records have the same format.

<u>Record Format</u>	<u>Type</u>	<u>Definition</u>
(HG(J) J=1 JMAX)	R*8	Real trial function defined at JMAX space points
<u>Read in Subroutine</u>	<u>Records</u>	<u>Reference Variables</u>
LIB	All	IDSN
<u>Written in Subroutine</u>	<u>Records</u>	<u>Reference Variables</u>
	All	IDSN

(4) Logical Record IV. There is one record for each energy group. Each record L contains the matrices $\{H_i\}_{i=1}^{IM1}$ for energy group L. Each matrix $H_{i,g}$ is packed and uses only the storage required, with all unused locations appearing at the end of each subarray. Thus, if $H_{i,g}$ is a 4 x 4 matrix stored in a 5 x 5 array, the first 16 storage locations are used and the remaining nine are unused. All records have the same format.

<u>Record Format</u>	<u>Type</u>	<u>Definition</u>
((H(N,I) N=1,NGKSQ), I=1,IM1)	R*8	Array H contains the matrices $\{H_i\}$, where NGKSQ is the square of the maximum number of real trial functions for any synthesis region and energy group. IM1 is one less than the number of space points in the direction of synthesis.
<u>Read in Subroutine</u>	<u>ords</u>	<u>Reference Variable</u>
SINCAL	All	NLIB
<u>Written in Subroutine</u>	<u>Records</u>	<u>Reference Variable</u>
MTQEN2	All	NLIB

(5) Logical Record V. There is one record for each energy group. Each record contains two-dimensional fluxes for energy group L.

<u>Record Format</u>	<u>Type</u>	<u>Definition</u>
((FLX(I I) J=1 JMAX) I=1 IMAX)	R*B	The two-dimensional fluxes, with IMAX space points in the synthesis direction and JMAX space points in the trial-function direction.

<u>Read in Subroutine</u>	<u>Records</u>	<u>Reference Variable</u>
FXVOL (entry in IFXVOL)	All	NTH

<u>Written in Subroutine</u>	<u>Records</u>	<u>Reference Variable</u>
SINOUT	All	NLIB

14 Data Set SCR002

* Name SCR002, Scratch Data Set 2

b. Description. This scratch data set is used by the module SYN2D to temporarily hold trial functions while creating data sets LIB ADJT LIB MIX and LIB REAL. SCR002 is used only if the real trial functions cannot be core-held. Next, SCR002 is used to hold the fission matrices $\{(x_g v_g, \Sigma_{fg})_k(r)\}$ for all refined regions and energy group combinations.

c. Structure and Content

(1) Logical Records I, II, and III. These are identical to items I, II, and III of SCR001 except that SCR002 holds the trial functions for energy group two. There are $\bar{N}$ records, where $\bar{N}$ is defined as for SCR001, $\bar{g} = 2$.

(2) Logical Record IV. This contains the fission matrices $\{(x_g v_g, \Sigma_{fg})_k(r)\}$. These matrices are packed. Refer to item IV of SCR001 for packing information. The total number of records is $R\bar{G}$, where R is the number of refined regions in the reactor and $\bar{G}$ is the number of energy groups. All records have the same format. Record $I = (\bar{G} - 1)\bar{G} + \bar{R}$ contains the fission matrices for refined region $\bar{R}$ energy group $\bar{G}$, for all C energy groups.

<u>Record Format</u>	<u>Type</u>	<u>Description</u>
((F(N, G), N=1, NGKSQ) G=1, GMAX)	R*B	Array F contains the fission matrices where KSQ is the square of the maximum number of real trial functions for any synthesis region and energy group and GMAX is the number of energy groups.

<u>Read in Subroutine</u>	<u>Records</u>	<u>Reference Variable</u>
SINCAI	All	ILIB
<u>Written in Subroutine</u>	<u>Records</u>	<u>Reference Variable</u>
COFGEN	All	IFISS

15. Data Set SCR003

a. Name. SCR003, Scratch Data Set 3.

b. Description. This scratch data set is used by the module SYN2D to temporarily hold trial functions while creating data sets LIB.ADJT, LIB.MIX, and LIB.REAL. SCR003 is used only if the trial functions cannot be core-held. Next, SCR003 is used to hold the matrices $\{U_i^{-1}\}_{i=1}^{IM1}$ and $\{V_i\}_{i=1}^{IM1}$ for all energy groups.

c. Structure and Content

(1) Logical Records I, II, and III. These are identical to items I, II, and III of SCR001, except that SCR003 holds the trial functions for energy group three. There are $\bar{N}$ records, where $\bar{N}$ is defined as for SCR001, $g = 3$.

(2) Logical/Record IV. This contains the matrices $\{U_i^{-1}\}_{i=1}^{IM1}$ and $\{V_i\}_{i=1}^{IM1}$ for all energy groups. These matrices are packed. Refer to item IV of SCR001 for packing information. There are two records for each energy group. Each two-record set has the same format.

<u>Record Format</u>	<u>Type</u>	<u>Definition</u>
((U(N,I), N=1,NGKSQ), I=1,IMAX)	R*8	Array U contains the matrices $\{U_i^{-1}\}$ where NGKSQ is the square of the maximum number of real trial functions for any synthesis region and energy group and IMAX is the number of space points in the direction of synthesis.
((V(N,I), N=1,NGKSQ), I=1,IM1)	R*8	Array V contains the matrices $\{V_i\}$, where IM is IMAX-1.

<u>Read in Subroutine</u>	<u>Records</u>	<u>Reference Variable</u>
SINCAI	1	ILIB
<u>Written in Subroutine</u>	<u>Records</u>	<u>Reference Variable</u>
COFGEN	All	ILIB

16. Data Set SCR004a. Name SCR004, Scratch Data Set 4

b. Description This scratch data set is used by module SYN2D to temporarily hold trial functions while creating data sets LIB.ADT, LIB.MIX, and LIB.REAL. SCR004 is used only if the real trial functions cannot be core-held. Next, SCR004 is used to hold the scattering matrices $\{E_{g'g,k}(r)\}$ for all refined regions and energy group combinations in which both g' and g are within the scattering band.

c. Structure and Content

(1) Logical Records I, II, and III These are identical to items I, II, and III of SCR001, except that SCR004 holds the trial functions for energy group four. There are $\bar{N}$ records, where $\bar{N}$ is defined as for SCR001, $g = 4$.

(2) Logical Record Number IV This contains the scattering matrices $\{E_{g'g,k}(r)\}$. These matrices are packed. Refer to item IV of SCR001 for packing information. The number of matrices varies from record to record, but for each group g a record contains the nonzero matrices for all g' . The records are structured so that the records for all refined regions appear for each energy group g .

<u>Record Format</u>	<u>Type</u>	<u>Definition</u>
((S(N,G),N=1,NGKSQ), G=GLOW,IUP)	R*8	Array S contains the scattering matrices. One record is used for each refined region, with NGKSQ the square of the maximum number of real trial functions for any synthesis region and energy group. GLOW = MAX(1,(G-MAXDN)) and IUP = MIN(GMAX,(G-MAXUP)). (If GLOW = IUP this record does not exist.) XDN is the maximum downscattering, XUP is the maximum upscattering. (If MAXUP and MAXDN are read from ARC S stem data set XS C MIN, record 1.) GMAX is the number of energy groups, and G is the present energy group number.

Read in Subroutine

SINCAL

CO

Reference Variable

AH

MLIB

Written in Subroutine

COFGEN

Records

AN

Reference Variable

LECAT

17. Data Set XS.C.MIN

- a. Name. XS C.MIN, Macroscopic Composition Cross Sections.
- b. Record Structure. ARC System data set.

<u>Read in Subroutines</u>	<u>Record Types</u>	<u>Reference Variables</u>
RCOMP	Type 1 of file 1.	N
RXSC01	Type 1 of file 1.	N
GETCHI	Type 2 of file 2.	NTAPE
RGROUP	Types 3 and 4 of file 2.	NTAPE
SYNGEN	Type 1 of file 1.	INEED

- c. Written in Subroutines. None.

18. Data Set XS.ISO2 or XS.ISO

- a. Name. XS ISO2, Problem-Dependent Microscopic Group Cross Sections or XS ISO, Microscopic Group Cross Sections.
- b. Record Structure. ARC System data set.

<u>Read in Subroutines</u>	<u>Record Types</u>	<u>Reference Variables</u>
RVEL	Type 3 of file 1	NTAPE

- c. Written in Subroutines. None.

19. Unnamed Scratch Data Sets

a. Description. Four scratch data sets, SCR001, SCR002, SCR003, and SCR004, are already supplied with the module SYN2D. However, in creating data sets LIB.ADJT, LIB.MIX, and LIB.REAL, one scratch data set must be provided for every energy group if the real trial functions cannot be core-held. Hence, for a six-group problem, for example, two additional scratch data sets must be supplied.

b. Structure and Content. Items I, II, and III are identical to items I, II, and III of SCR001, except that the Ith user-supplied scratch data set holds the trial functions for (I+4)th energy group. There are N records, where N is defined as for 001, $g = (I+4)$. Refer to Section II.D.1.c for restrictions on reference a catalogue procedure ARCSPO12.

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